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Ballast water management that adapts to climate changes and reduces harmful bio-invasions in marine eco-systems

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3rd International Symposium

Effects of Climate Change on the World’s Oceans

March 21–27, 2015
Santos, Brazil

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Abstracts for oral presentations are sorted first by date and then by presentation time. Abstracts for posters are sorted by session and then by paper ID number. Presenter name is in bold-face type and underlined.

Welcome

We are honoured to welcome you to the Third International Symposium on "*Effects of Climate Change on the World's Oceans*", which has established itself as a major and regular event for the oceanography and climate change scientific communities, following events in Gijon, Spain (May 2008) and Yeosu, Korea (May 2012). This time the Symposium takes place in Santos, Brazil, bringing the event to the lively, growing and exciting scientific community in South America.

The current pressures and impacts on our oceans are calling for blueprints of good management practice to secure the sustainability of ocean and coastal systems. These good practices must be scientifically underpinned and respond to political imperatives. In fact, the debate around climate change has relied heavily on excellent and innovative science, and on adequately communicating this science to stakeholders and policy makers, but blueprints of good practice are yet to emerge. While the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (2007) was criticized for lacking specificity on the impacts of climate change on ocean ecosystems, the 2014 Fifth Assessment Report included two chapters dedicated to marine ecosystems. The science of climate change is maturing, and this Symposium will demonstrate this further, showcasing the novel science that will influence the Sixth Assessment Report, as well as other global initiatives such as the United Nations Regular Process for Global Reporting and Assessment of the State of the Marine Environment. As such, it is a unique opportunity for researchers to engage in science issues of global importance and give science a voice and a mechanism to influence policy. Linking science to global assessments puts an immense responsibility on the scientific community to synthesize independent, impartial and excellent evidence. While climate change issues are high on the political agenda, we are still far from achieving a global commitment to reduce greenhouse gas emissions. The debate needs the continued input from science as one of the essential elements, and this Symposium in Santos is crucial to consolidate and share our understanding and knowledge.

This Symposium aims to review achievements in climate change research impacts on ocean and marine ecosystems, and intends to set the research agenda for the next few years. Our speakers include key players in different facets of this large and complex science, representing views from academia to policy making and covering a variety of temporal and spatial scales and geographical locations.

We would like to thank the Secretariats of the convening organizations PICES, IOC and ICES, and especially the Local Organizing Committee, for their efforts that ranged from operational preparations to fundraising for this event. They have worked hard to ensure that all arrangements for the large number of theme sessions and workshops will run smoothly. The Symposium gathers more than 300 participants from approximately 40 countries, and confirms the breadth, richness and vitality of scientific interests of the South American community, which is represented by about 80 experts.

We want to thank all the institutions for the trust they placed in us when we asked for support for this Symposium. Without their commitment and decisive support, our aims would have been impossible to achieve. Our sincere thanks and congratulations must also go to the Scientific Steering Committee for their work in mobilizing a wide representation of scientific teams attending the meeting.

Not only will this Symposium give us an opportunity to discuss our ongoing research, progress and plans, it will also give us a chance to deliberate on the institutional challenges that we face in our various responsibilities and capacities. We are sure that all of you will have a scientifically productive meeting and that you will also enjoy the social events, sights, foods, and hospitality of Brazil.

Jacquelynne King, Manuel Barange, Luis Valdés, Alexander Turra,
Alexander Bychkov, Adolf Kellermann, Michel M. de Mahiques and Julia Yazvenko

Symposium convenors and coordinators

Symposium Organizers

Symposium Convenors

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Institut de Recherche pour le Développement and
University of Cape Town, France/South Africa

Primary Sponsors

ICES
International Council for the Exploration of the Sea

PICES
North Pacific Marine Science Organization

IOC
Intergovernmental Oceanographic Commission of UNESCO

IOUSP
Instituto Oceanográfico da Universidade de São Paulo
Oceanographic Institute of the University of São Paulo

Co-Sponsoring Organizations

Governo Federal do Brasil
Brazilian Federal Government

MEC
Ministério da Educação
Ministry of Education, Brazil

CAPES
Coordenação de Aperfeiçoamento de Pessoal de Nível Superior
Coordination for the Improvement of Higher Education Personnel

CNPq
Conselho Nacional de Desenvolvimento Científico e Tecnológico
The Brazilian Science Council

FAPESP
Fundação de Amparo à Pesquisa do Estado de São Paulo
São Paulo Research Foundation

FUNDESPA
Fundação de Estudos e Pesquiasas Aquáticas
Aquatic Education and Research Foundation

IAEA/OA-ICC
International Atomic Energy Agency, Ocean Acidification International Coordination Centre

IMBER
Integrated Marine Biogeochemistry and Ecosystem Research

ITAU

LabHidro
Laboratório de Hidrometeorologia – IAG-USP Programa SIHESP/FARESP

NOAA
U.S. National Oceanic and Atmospheric Administration

NPRB
North Pacific Research Board

ONR-Brazil
Office Naval Research / Escritório de Pesquisa Naval

SCOR
Scientific Committee on Oceanic Research

SOLAS
Surface Ocean-Lower Atmosphere Study

Notes for Guidance

Registration

The registration desk will be located at the entrance to the Diamante complex from March 20 (3 p.m.) to March 27.

Location for the Sessions and Workshops

All sessions and workshops will be convened at the Diamante complex. Some Workshop Breakout Groups will meet in the Pérola complex (see floor plan).

Presentations

In order to allow the sessions to run smoothly, and in fairness to other speakers, all presentations are expected to adhere strictly to the time allocated. All authors should designate at least 3 minutes for questions.

Authors can download their presentations straight to the computers where the session/workshop will be held.

Important: Please rename your files: time-name.ppt (*e.g.* 0900-Smith.ppt, 1530-Kim.ppt).

If complications occur due to incompatibilities between PCs and Macs, Macintosh owners may use their own computers to make presentations.

Posters

All posters will be on display during the entire Symposium, from March 23-27; workshop posters can be viewed starting March 21. An evening Poster Session (with appetizers and drinks) will be held from 18:30-20:30 on March 24, when poster presenters are expected to be available to answer questions.

Social activities

Welcome Reception (all participants)
March 23, 19:00-22:30
Location: Point 44 chopperia (within walking distance from Mendes Plaza)
http://www.point44.com.br

Symposium Dinner (all participants)
March 25, 18:30-22:00
Location: Churrascaria Tertulia
http://www.churrascariatertulia.com.br/
Transportation will be provided.

Free afternoon
March 26, starting at12:40
A tourism agent will be available on site from March 23.

- Santos City Tour (Beach, Historic Centre and a tour by streetcar, 4 hours)
- Boat tour and visit to the Fisheries Museum and Aquarium (4 hours)
- Visit to the Coffee Museum and Pelé Museum (includes a tour by streetcar, 4 hours)
- Tour to Guarujá City (famous for its beaches, 4 hours)

Contacts and reservations also can be made via phone 55 13 33075254 or email contato@valongotour.com.br

Useful information

- A Food Court is available on the second floor of Miramar Shopping Centre, located beside the Mendes Hotel. Other options are available around the hotel.
- A foreign currency exchange office is located on the first floor of the Miramar Shopping Centre.
- The beach is located two blocks from the venue. Participants should be careful with safety and note the Green/Red flags indicating water quality.
- Dehydration can be a problem, especially for people who are not accustomed to high (average around 30°C) daily air temperatures. Coconut water is a natural remedy.

Symposium Timetable

Saturday, March 21

08:55	W2/W6 Workshop [Diamante 6-7]	W3 Workshop [Diamante 2]	W4 Workshop [Diamante 1]	W5 Workshop [Diamante 3]
12:30	*Lunch*			
14:00 18:00	W2/W6 Workshop [Diamante 6-7]	W3 Workshop [Diamante 2]	W4 Workshop [Diamante 1]	W5 Workshop [Diamante 3, 5; Pérola 2, 3]

Sunday, March 22

08:55	W1 Workshop [Diamante 5]	W2/W6 Workshop [Diamante 6-7]	W3 Workshop [Diamante 2]	W4 Workshop [Diamante 1]	W5 Workshop [Diamante 3]
12:30	*Lunch*				
14:00 18:00	W1 Workshop [Diamante 5]	W2/W6 Workshop [Diamante 6-7]	W3 Workshop [Diamante 2; Pérola 15,16]	W4 Workshop [Diamante 1]	W5 Workshop [Diamante 3; Pérola 2-5]

Monday, March 23

08:45	**Opening Ceremony**	
09:15	**Keynote Speaker** Chris Field (Carnegie Institution for Science, CA, USA) Mapping the problem space and the opportunity space	
10:15	Coffee Break	
	DAY 1 PLENARY SESSION [Diamante 1-3]	
10:45	**Plenary Speaker (Session 4)** Arne Biastoch (GEOMAR Helmholtz Centre for Ocean Research, Germany) The potential of nested ocean modeling	
11:20	**Plenary Speaker (Session 5)** Margareth Copertino (Universidade Federal do Rio Grande, Brazil) Blue carbon ecosystems from South America: The role on carbon sequestration and mitigation of climate changes	
11:55	**Plenary Speaker (Session 6)** Lynda Chambers (Bureau of Meteorology, Phillip Island Nature Parks, Australia) Phenology responses of southern marine species to climate: Impacts and adaptation options	
12:30	*Lunch*	
13:35	**Session 4** [Diamante 1-3]	**Session 6** [Diamante 5-6]
15:30	*Coffee/Tea Break*	
16:00 18:00	**Session 4**	**Session 6**
19:00 22:30	**Welcome Reception** [Point 44 chopperia]	

Symposium Timetable (continued)

<table>
<tr><td colspan="4">Tuesday, March 24</td></tr>
<tr><td colspan="4">DAY 2 PLENARY SESSION
[Diamante 1-3]</td></tr>
<tr><td>09:00</td><td colspan="3">Plenary Speaker (Session 1)
Paulo H.R. Calil (Institute of Oceanography, Rio Grande, Brazil)
Multi-scale physical-biological interactions in the ocean -
The importance of submesoscale processes</td></tr>
<tr><td>09:35</td><td colspan="3">Plenary Speaker (Session 10)
Patrick Lehodey (Space Oceanography Division, CLS, France)
Forecasting climate change impacts on large pelagic fish populations and fisheries:
Progress, uncertainties and research needs</td></tr>
<tr><td>10:10</td><td colspan="3">Plenary Speaker (Session 12)
Laura Richards (North Pacific Marine Science Organization)
Looking back to go forward: Do past management actions foreshadow
management responses to climate change?</td></tr>
<tr><td>10:45</td><td colspan="3">Coffee/Tea Break</td></tr>
<tr><td>11:15</td><td>Session 1
[Diamante 5]</td><td>Session 10 (Day 1)
[Diamante 1-3]</td><td>Session 12
[Diamante 6-7]</td></tr>
<tr><td>12:30</td><td colspan="3">Lunch</td></tr>
<tr><td>14:00</td><td>Session 1</td><td>Session 10 (Day 1)</td><td>Session 12</td></tr>
<tr><td>15:40</td><td colspan="3">Coffee Break</td></tr>
<tr><td>16:10
18:10</td><td>Session 1</td><td>Session 10 (Day 1)</td><td>Session 12</td></tr>
<tr><td>18:30
20:30</td><td colspan="3">Poster Session / Reception</td></tr>
<tr><td colspan="4">Wednesday, March 25</td></tr>
<tr><td colspan="4">DAY 3 PLENARY SESSION
[Diamante 1-3]</td></tr>
<tr><td>09:00</td><td colspan="3">Plenary Speaker (Session 2)
Jean-Pierre Gattuso (Laboratoire d’Océanographie de Villefranche, CNRS and
Université Pierre et Marie Curie-Paris, France)
Ocean acidification: Knowns, unknowns and perspectives</td></tr>
<tr><td>09:35</td><td colspan="3">Plenary Speaker (Session 8)
Lisa Levin (Center for Marine Biodiversity and Conservation,
Scripps Institution of Oceanography, UC San Diego)
Biodiversity consequences of climate change in the deep ocean</td></tr>
<tr><td>10:10</td><td colspan="3">Plenary Speaker (Session 11)
Edward Allison (School of Marine and Environmental Affairs, University of Washington, USA)
From climate physics to coastal people:
What do we know about climate change and its potential impacts on coastal populations?</td></tr>
<tr><td>10:45</td><td colspan="3">Coffee/Tea Break</td></tr>
<tr><td>11:15</td><td>Session 2 (Day 1)
[Diamante 6-7]</td><td>Session 8 (Day 1)
[Diamante 1-3]</td><td>Session 11
[Diamante 5]</td></tr>
<tr><td>12:30</td><td colspan="3">Lunch</td></tr>
<tr><td>14:00
18:10</td><td>Session 2 (Day 1)</td><td>Session 8 (Day 1)</td><td>Session 11</td></tr>
<tr><td>18:30
22:00</td><td colspan="3">Symposium Dinner
[Churrascaria Tertulia]</td></tr>
</table>

Symposium Timetable (continued)

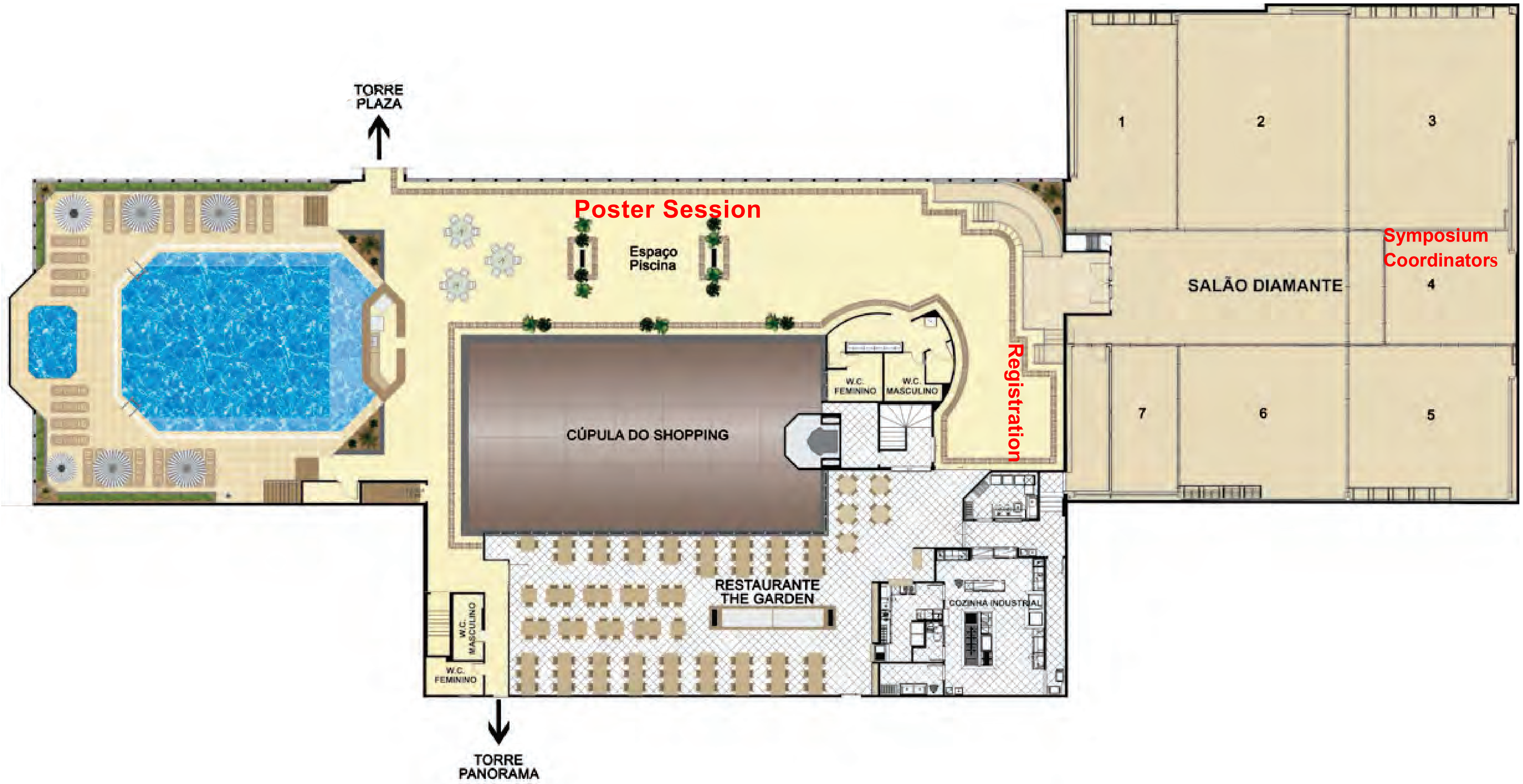
Thursday, March 26				
08:55	**Session 2 (Day 2)** [Diamante 6-7]	**Session 8 (Day 2)** [Diamante 1-2]	**Session 10 (Day 2)** [Diamante 3]	
10:40	*Coffee/Tea Break*			
11:10	**Session 2 (Day 2)**	**Session 8 (Day 2)**	**Session 10 (Day 2)**	
12:40	Free time			
Friday, March 27				
	DAY 4 PLENARY SESSION [Diamante 2-3]			
09:00	**Plenary Speaker (Session 3)** Micha Rijkenberg (Royal Netherlands Institute for Sea Research, The Netherlands) Bio-essential and pollutant trace metals in a changing Atlantic Ocean			
09:35	**Plenary Speaker (Session 7)** Philip Munday (ARC Centre of Excellence for Coral Reef Studies/School of Marine and Tropical Biology, James Cook University, Australia) Predicting evolutionary responses to climate change in the sea: Progress and challenges			
10:10	**Plenary Speaker (Session 9)** Coleen Moloney (University of Cape Town, South Africa) Going nowhere or moving on: How do changes in species distribution impact marine food webs?			
10:45	*Coffee/Tea Break*			
Friday, March 27 (continued)				
11:15	**Session 3** [Diamante 5]	**Session 7** [Diamante 1]	**Session 8 (Day 3)** [Diamante 2-3]	**Session 9** [Diamante 6-7]
12:30	*Lunch*			
14:00	**Session 3**	**Session 7**	**Session 8 (Day 3)**	**Session 9**
15:40	*Coffee/Tea Break*			
16:10	**General Plenary and Closing Ceremony**			
17:30	Symposium ends			

Coffee/Tea Breaks will take place every day in the morning and afternoon.

List of Sessions and Workshops

S1	Role of advection and mixing in ocean biogeochemistry and marine ecosystems
S2	Ocean acidification
S3	Changing ocean chemistry: From trace elements and isotopes to radiochemistry and organic chemicals of environmental concern
S4	Regional models for predictions of climate change impacts: Methods, uncertainties and challenges
S5	Coastal blue carbon and other ocean carbon sinks (Plenary talk and Posters only, Session description p.220)
S6	Climate change in the seasonal domain: Impacts on the phenology of marine ecosystems and their consequences
S7	Evolutionary response of marine organisms to climate change
S8	Climate change impacts on marine biodiversity and resilience
S9	Impact of climate change on ecosystem carrying capacity via food-web spatial relocations
S10	Forecasting climate change impacts on fish populations and fisheries
S11	Impacts on coastal communities
S12	Linking climate change to marine management objectives
W1	Addressing uncertainty in projecting climate change impacts in marine ecosystems
W2/W6	Joint Brazilian Ocean Acidification Research and Surface Ocean-Lower Atmosphere Study (SOLAS) Workshop: Biogeochemical-physical interactions and feedbacks between the ocean and atmosphere
W3	Effects of climate change on the biologically-driven ocean carbon pumps
W4	Upwelling systems under future climate change
W5	Moving towards climate-ready fishery systems: Regional comparisons of climate adaptation in marine fisheries

DIAMANTE complex floor plan



PÉROLA complex floor plan
(rooms for workshops only)

Schedules
Oral Presentations

Saturday-Sunday, March 21-22

Workshop 2 and 6 W2/W6

Joint Brazilian Ocean Acidification Research and Surface Ocean-Lower Atmosphere Study (SOLAS) Workshop: Biogeochemical-physical interactions and feedbacks between the ocean and atmosphere

Co-Convenors:
Ruy Kikuchi (Bahia Federal University, Brazil)
Leticia C. da Cunha (Rio de Janeiro State University, Brazil)
Rodrigo Kerr (Rio Grande Federal University, Brazil)
Michelle Graco (Instituto del Mar del Perú, Peru)

Invited Speakers:
Silvana Birchenough (Cefas, UK)
Rosane G. Ito (Federal University of Rio Grande, Brazil)
Arne Körtzinger (GEOMAR Helmholtz Centre for Ocean Research, Germany)
Christian Vargas (Universidad de Concepción, Chile)

The Brazilian Ocean Acidification Research Group (BrOA; www.broa.furg.br) was created in December 2012, as an action of the activities of the workshop "Studying Ocean Acidification and its Effects on Marine Ecosystems" (Dec. 4-6, 2012, Cananéia, Brazil). BrOA operates in distinct environments along the Brazilian coast, including coastal and estuarine ecosystems and oceanic open waters.

The International Surface Ocean - Lower Atmosphere Study (SOLAS) project is an international research initiative aiming to understand the key biogeochemical-physical interactions and feedbacks between the ocean and atmosphere. For more than ten years, SOLAS has been fostering cutting-edge research in air-sea interactions, as well as promoting communication and integration of different research groups all over the world.

The focus of this joint workshop is to bring together the the international community that conducts research on sea-air CO_2 fluxes and their implication to ocean biogeochemistry (*e.g.* ocean acidification, changes in ocean biogeochemistry), as well as on the response of marine organisms to ocean acidification effects (bio-assays), paleoceanography and proxies of past ocean acidification events and carbonate system, and marine ecosystem modeling.

We encourage participation from BrOA and SOLAS researchers. The workshop will combine invited and selected talks, along with breakout group discussions corresponding to the main BrOA network and SOLAS topics. The general content of presentations, along with summations of general and breakout group discussions will be included in the Third BrOA Report/SOLAS Workshop Report. Here, participants will assess the advances in analytical methods and reporting scientific data on sea-air gas fluxes and ocean biogeochemistry, and the regional needs to study ocean acidification and sea-air gas fluxes, such as analytical and logistic facilities, data access, or capacity building. Activities of emerging research groups (*e.g.* Latin America, Asia, Africa) will also be reported. In addition it is anticipated that a journal manuscript assessing the state of the art of ocean acidification studies in South America will be prepared.

Saturday, March 21, Day 1 (08:55-18:00)

08:55 ***Introduction by Convenors***

09:00 **Rosane Gonçalves Ito (Invited)**
Ocean acidification studies: The Brazilian contribution (W2/W6-9897)

09:30 **Cristián Vargas, Marco Lardies, Bernardo Broitman, Cristian Duarte and Nelson Lagos (Invited)**
Toward the establishment of a Latin-American Ocean Acidification Network (LAOCA): The Chilean experience in OA research (W2/W6-10057)

10:00 **Silvana Birchenough, John K. Pinnegar, Matthew B. Sanders and Jeo Lee (Invited)**
Understanding ocean acidification: What will be the consequences for commercial species? (W2/W6-10220)

10:30 ***Coffee/Tea Break***

11:00 **Arne Körtzinger (Invited)**
Sensing marine carbon and oxygen dynamics with autonomous observation approaches (W2/W6-10187)

11:30 **Manfredi Manizza, Laure Resplandy, Sara Mikaloff-Fletcher, Cynthia D. Nevison and Ralph F. Keeling**
Testing ocean biogeochemical models using combined measurements of atmospheric potential oxygen (APO) and Ar/N_2 ratio and oxygen/heat oceanic fluxes (W2/W6-10085)

11:50 **Leticia C. da Cunha, Cíntia W. Coelho, Pedro W. Santos, Ricardo Keim, Helen Soares, Michelle P. Araújo, Cássia de O. Farias and Claudia Hamacher**
A snapshot of the marine CO_2-system in three coastal ecosystems in SE Brazil (W2/W6-10169)

12:10 **Rodrigo Kerr, Leticia Cotrim da Cunha and Ruy Kenji P. Kikuchi**
On the progress of the Brazilian Ocean Acidification Research Group: Two years of activities (W2/W6-9818)

12:30 ***Lunch***

14:00 **Marius N. Müller**
Ocean acidification experiments on coccolithophores under controlled laboratory conditions (W2/W6-9799)

14:20 **Pamela Muñoz, Ellie Bergstrom, Cintia Martins, Eduardo Bastos, Alessandra Fonseca, José Bonomi, Leonardo Rorig and Paulo Horta**
Ecophysiological responses of *Lithothamnion crispatum* and *Sonderophycus capensis* to alterations in temperature, pCO_2 and nutrients (W2/W6-10233)

14:40 **Barbara R. Pinheiro, Felipe L. Gaspar, Manuel J. Flores-Montes and Nathalie Lefèvre**
Seasonal and diel CO_2 fluxes variability at Rocas Atoll-RN (W2/W6-10180)

15:00 **Adriana R. Perretti, Cristiano M. Chiessi and Ana Luiza S. Albuquerque**
Evaluating qualitative dissolution indexes as proxies for ocean carbonate chemistry (W2/W6-9888)

15:20 **Manoela R. de Orte, T. Ángel DelValls, Augusto Cesar and Inmaculada Riba**
The use of multiple lines of evidences to conduct risk assessment in sediments affected by CO_2 acidification (W2/W6-10224)

15:40 ***Coffee/Tea Break***

16:10 **Group Discussion 1**
Attendees will split into discussion groups, according to their own preferences.
I - SOLAS report:synthesis of the state-of-the-art procedures and advances being made for collecting, analyzing, modelling, and reporting scientific data on sea-air gas fluxes and ocean biogeochemistry for coastal/shelf and open ocean areas. The report will identify regional needs to study sea-air gas fluxes, such as analytical and logistic facilities, data access, or capacity building.

18:00 Day 1 Workshop ends

Sunday, March 22, Day 2 (08:55-18:00)

08:55 ***Introduction by Convenors***

09:00 **Group Discussion 2**
Attendees will split into discussion groups, according to their own preferences.
II – Linking BrOA to international ocean acidification programs: (i) strengthening the scientific collaboration between Brazil and other countries in the context of ocean acidification research;(ii) identifying successes and failures in the implementation of ocean acidification.

10:30 ***Coffee/Tea Break***

11:00 **Group Discussion 3**
Attendees will split into discussion groups, according to their own preferences.
III – BrOA: (i) identifying national ocean acidification projects and learning how they have integrated field and laboratory/analytical studies; (ii) identifiying researchers to lead or coordinate potential BrOA sub-groups and activities; (iii) outline of 3rd BrOA report.

11:45 **Group Discussion 4**
Attendees will split into discussion groups, according to their own preferences.
IV – Manuscript outline: OA research in South America → recent advances, learning from experience, perspectives, challenges, potential partners.

12:30 ***Lunch***

14:00 **Group Discussion 4 (Continued)**

15:40 ***Coffee/Tea Break***

16:10 **Group Discussion 4 (Continued)**

18:00 Workshop ends

Saturday-Sunday, March 21-22

Workshop 3 W3

Effects of climate change on the biologically-driven ocean carbon pumps

Co-Convenors:
Curtis Deutsch (University of Washington, School of Oceanography, USA)
Nianzhi Jiao (Xiamen University, State Key Laboratory of Marine Environmental Science, China)
Louis Legendre (Pierre & Marie Curie University, Oceanography Laboratory, France)
Uta Passow (University of California Santa Barbara, Marine Science Institute, USA)

Invited Speakers:
Thorsten Dittmar (University of Oldenburg, Germany)
Marion Gehlen (Laboratoire des Sciences du Climat et de L'Environnement, France)
Phoebe Lam (University of California, Santa Cruz, USA)

The transfer of atmospheric CO_2 into the ocean is the largest carbon sink on Earth. The best known mechanisms for the sequestration of marine carbon are three vertical ocean carbon pumps, *i.e.* solubility, carbonate and soft-tissue or organic ("biological carbon pump", BCP). The latter two pumps are biologically-driven. The carbonate pump consists in the precipitation of calcium carbonate in surface waters by calcifying organisms followed by sinking of the resulting bio-minerals to depth. The BCP is driven by primary production in the euphotic zone, followed by the transfer of carbon to depth by sinking of particulate organic carbon, by vertical migrations of zooplankton, and by vertical transport of dissolved organic carbon (DOC) by physical processes, like mixing and convection. An additional biological mechanism of ocean carbon sequestration was recently described under the name of microbial carbon pump (MCP). The vertical carbon pumps transport carbon from surface to depth, whereas the MCP transforms short-lived DOC into long-lived DOC. (Technically, the vertical carbon pumps maintain the gradient in total inorganic carbon between surface and deep waters, and the MCP maintains a concentration gradient between short- and long-lived DOC). Carbon is chemically sequestered in long-lived DOC at any depth in the water column. The MCP consists in the microbial transformation of labile organic carbon to refractory DOC (RDOC). In the deep ocean, the huge pool of RDOC accounts for >90% of the total marine organic carbon, and has an average residence time of ~5000 years. As the amount of carbon existing as RDOC is equivalent to the total inventory of atmospheric CO_2, changes in some of the processes that regulate the RDOC pool may be important factors in carbon cycling and climate change.

The quantitative roles played by the three biologically-driven ocean carbon pumps (*i.e.* carbonate pump, BCP, and MCP) is a subject of active research by field oceanographers, experimental biogeochemists, marine ecologists, and carbon-cycle modellers, but these research communities work largely independently. Hence, they often reach conclusions that are quite different. The proposed workshop intends to bring together specialists of field observations (including paleoceanographers), experimentalists and modellers who work on one or more of the three biologically-driven ocean carbon pumps. The objectives of the workshop address the possibility that the three biologically-driven ocean carbon pumps are highly responsive to climate change. Predicting these responses requires an understanding and quantification of the mechanisms that control the responses to environmental forcing.

The workshop will be comprised of four sessions. Sessions 1 to 3 will be dedicated to the three approaches (*i.e.* field-observational, experimental, and modelling, respectively) used to investigate the biologically driven ocean carbon pumps. Goals within each of these sessions include familiarizing all participants with the different perspectives, identifying the main stumbling blocks and challenges that presently exist, reviewing new results, and discussing developments and actions needed to make progress in coming years. Examples of processes to be discussed include: plankton community structure, stoichiometry, particle dynamics, bacterial remineralization, and production and removal of RDOC. Discussion periods will try to elucidate consensus views among the different approaches on the study of biologically-driven ocean carbon pumps. Session 4 will build on the results of the previous sessions to outline and draft a white paper. This paper will focus on multidisciplinary developments needed to address the responses of the biologically-driven ocean carbon pumps to climate change, and their feedbacks to the climate. The white paper will be submitted for publication in the peer-reviewed literature. Necessary studies to address responses and feedbacks of biologically-driven ocean carbon pumps will be identified, relevant approaches will be described; required national and international tools (*e.g.* research programs and infrastructures) will be identified; and strategies to achieve these goals will be proposed.

Saturday, March 21, Day 1 (08:55-18:00)

08:55	***Introduction by Convenors***
09:00	**Phoebe J. Lam (Invited)** Observational approaches to the biologically-driven ocean carbon pumps (W3-10004)
09:30	**DanLing Tang** (Discussion Leader) Discussion: Scientific issues following from the Introductory talk
10:00	**Group 1 Poster Session** New achievements in observational research
10:30	***Coffee/Tea Break***
11:00	**Group 1 Poster Session (Continued)** New achievements in observational research
11:30	**Rosabruna La Ferla (Discussion Leader)** Discussion: Scientific issues following from the posters
12:00	**Cindy Pilskain (Discussion Leader)** Discussion: Developments and actions needed in coming years
12:30	***Lunch***
14:15	**Thorsten Dittmar (Invited)** Current hypotheses explaining the long-term stability of marine dissolved organic matter (W3-9883)
14:45	**Chuanlun Zhang (Discussion Leader)** Discussion: Scientific issues following from the Introductory talk
15:20	**Group 2 Poster Session** New achievements in experimental approaches
15:40	***Coffee/Tea Break***
16:10	**Group 2 Poster Session (Continued)** New achievements in experimental approaches
16:50	**Sari Giering (Discussion Leader)** Discussion: Scientific issues following from the posters
17:25	**Richard B. Rivkin (Discussion Leader)** Developments and actions needed in coming years
18:00	Day 1 Workshop ends

Sunday, March 22, Day 2 (08:55-18:00)

08:55 ***Introduction by Convenors***

09:00 **Marion <u>Gehlen</u> (Invited)**
The future of the ocean carbon pumps: A modeling perspective (W3-9940)

09:30 **Fei <u>Chai</u> (Discussion Leader)**
Discussion: Scientific issues following from the Introductory talk

10:00 **Group 3 Poster Session**
New achievements in numerical and conceptual models

10:30 ***Coffee/Tea Break***

11:00 **Group 3 Poster Session (Continued)**
New achievements in numerical and conceptual models

11:30 **Charlotte <u>Laufkoetter</u> (Discussion Leader)**
Scientific issues following from the posters

12:00 **Adrian <u>Burd</u> (Discussion Leader)**
Developments and actions needed in coming years

12:30 ***Lunch***

14:15 **Convenors (Discussion)**
Content of the white paper and assignment of participants to 4 breakout Writing Groups

14:50 **Stephanie <u>Henson</u>, Richard <u>Lampitt</u>, Marlon <u>Lewis</u> (Writing Group Leaders)**
Breakout writing groups

15:40 ***Coffee/Tea Break***

16:10 **Stephanie <u>Henson</u>, Richard <u>Lampitt</u>, Marlon <u>Lewis</u> (Writing Group Leaders)**
Breakout writing groups (Continued)

17:30 **Convenors (Discussion)**
Reports of the writing groups and plans for completing the white paper

18:00 Workshop ends

Saturday-Sunday, March 21-22

Workshop 4 W4

Upwelling Systems Under Future Climate Change

Co-Convenors:
Kenneth Drinkwater (Institute of Marine Research, Norway)
Shoshiro Minobe (Graduate School of Science, Hokkaido University, Japan)

Invited Speakers:
Enrique Curchitser (Rutgers University, USA)
William Sydeman (Farallon Institute for Advanced Ecosystem Research, USA)

Ocean upwelling regions contain the most productive fisheries in the world accounting for around 25% of the global catch. This fish production results from upwelled nutrients that lead to high primary and secondary production. Characteristically, fisheries in upwelling areas are dominated by small and medium sized schooling pelagic fish, especially sardine and anchovy that contribute significantly to the annual global fish production. Bakun (1990) proposed increased winds in eastern boundary currents (EBCs) under climate change will result in increased upwelling. While evidence for recent increased upwelling has been found in some EBCs, other EBCs and upwelling regions have shown decreased upwelling intensity or had no trend at all. As such it has recently been suggested that Bakun's hypothesis was over simplified and it is not clear that there will be increased upwelling in EBCs, at least the Pacific, in the future. Clearly more work is needed to determine the future state of upwelling, not only in EBCs, but in other upwelling types. Upwelling systems typically have been poorly represented in global models owing to the small spatial scales of the upwelling relative to the horizontal resolution of the global models. Indeed, EBCs are often associated with warm temperature biases in the model results that strongly limit the prediction of future evolution. Also, it is not simply local winds that affect upwelling but basin-scale physics needs to be considered to understand and simulation regional upwelling variability. For these reasons the most recent high resolution global model results, as well as available regional models of upwelling regions, are needed to meet some of the challenges in developing upwelling scenarios under future climate change. Also, any attempt to predict future fisheries yields in upwelling areas in relation to global warming needs to consider retrospective studies of the impact of climate variability of anchovies and sardines.

The main objective of the workshop is to investigate the potential effects of climate change on upwelling systems. The most recent available global and regional models will be used to determine future scenarios in the upwelling regions of the world's oceans. These, together with information on the present trends in upwelling, will be used to determine the likely impacts on the primary and secondary production and further on fish and fisheries. This will be undertaken using a combination of retrospective analyses and ecosystem modeling. Examination of several of the major upwelling areas around the globe, *e.g.* within eastern and western boundary currents, along the equator, in the Indian Ocean, in Polar Regions, *etc*. will allow comparisons between regions. The workshop will also cover physical, biogeochemical, biological, fish and fisheries dynamics. The workshop will consist of invited and contributed talks that will focus upon (1) future climate scenarios in upwelling regions around the globe and (2) recent observed trends in these regions. Breakout groups will discuss the likely impacts of the future upwelling scenarios on the physics and biogeochemistry, as well as the biology, including fish and fisheries and will identify what additional research is needed. Plenary presentations and discussions from the breakout groups will allow interactions between disciplines and trophic levels.

Several outputs will produced from this workshop. The workshop stems from a CLIVAR/IMBER/SOLAS working group and a workshop report will be presented to these global change projects. A journal paper on the recent upwelling trends in as many of the world's upwelling regions and on their physical and biogeochemical (*e.g.* oxygen) scenarios under future climate change is also planned. The expected impact of future change on anchovies and sardines will either be highlighted in the workshop report or in a separate paper focused only upon this topic, a decision that will be made during the workshop. The results of the work on anchovies and sardines will be presented at the planned joint 2016 PICES/ICES Symposium on "Drivers of Dynamics of Small Pelagic Neritic Fish Resources."

Saturday, March 21, Day 1 (09:00-18:00)

09:00 ***Introduction by Convenors***

09:30 **Enrique Curchitser, Justin Small, William Large, Kate Hedstrom and Brian Kaufman (Invited)**
Regional and global ramifications of eastern boundary upwelling (W4-9970)

10:00 **Shoshiro Minobe**
Spatio-temporal structure of upwelling in an eddy resolving quasi-global GCM (W4-10114)

10:20 **Discussion**

10:30 ***Coffee/Tea Break***

11:00 **Nele Tim, Eduardo Zorita and Birgit Hünicke**
Simulating the variability of eastern boundary upwelling over the past millennium (W4-10154)

11:20 **Michael G. Jacox, Steven J. Bograd and Elliott L. Hazen**
Upwelling intensity, stratification, and nutrient supply trends in the California Current System (W4-10191)

11:40 **Marisol García-Reyes, William J. Sydeman, David S. Schoeman, Ryan R. Rykaczewski, Bryan A. Black, Sarah Ann Thompson, Arthur Miller, Andrew Bakun and Steven J. Bograd**
Climate change and coastal upwelling drivers (W4-10205)

12:00 **Patrícia Laginha Silva, Paulo Relvas and A. Miguel P. Santos**
Decadal variability of the Iberian Margin subsurface structure in response to global warming (W4-10219)

12:20 **Discussion**

12:30 ***Lunch***

14:00 **Kenneth F. Drinkwater**
Upwelling in the Arctic and Antarctic under climate change (W4-10217)

14:20 **William J. Sydeman and the Past, Present and Future of Upwelling Team (Invited)**
Of fish, seabirds, and trees: Present, past, and future of upwelling ecosystems (W4-10147)

14:50 **Discussion**

15:40 ***Coffee/Tea Break***

16:10 **Discussion**

18:00 Day 1 Workshop ends

Sunday, March 22, Day 2 (09:00-17:00)

09:00	**Breakout Groups/Discussion**
10:30	***Coffee/Tea Break***
11:00	**Breakout Groups/Discussion**
12:30	***Lunch***
14:00	**Breakout Groups/Discussion**
15:40	***Coffee/Tea Break***
16:10	**Reports/Summary**
17:00	Workshop ends

Saturday-Sunday, March 21-22

Workshop 5 W5

Moving towards climate-ready fishery systems: Regional comparisons of climate adaptation in marine fisheries

Co-Convenors:
Roger Griffis (National Oceanic and Atmospheric Administration, USA)
Alan Haynie (Alaska Fisheries Science Center, USA)
Katherine Mills (Gulf of Maine Research Institute, USA)
Gretta Pecl (University of Tasmania, Australia)
Andrew Pershing (Gulf of Maine Research Institute, USA)

Invited Speakers:
Manuel Barange (Plymouth Marine Laboratory, UK)
Jason Link (NOAA Fisheries, USA)
Leif Nøttestad (Institute of Marine Research, Norway)
John Pinnegar (Centre for Environment, Fisheries & Aquaculture Science, UK)
Éva Plagányi-Lloyd (CSIRO, Australia)

The impacts of climate change on marine ecosystems and fish populations are being increasingly recognized and are expected to increase as warming trends, extreme warm events, and ocean acidification become more pronounced. While these impacts have been documented and compared across regions, much less attention has been devoted to understanding how fisheries—particularly the fishing industry and the management and governance systems that regulate harvesting—are responding to these changes. By comparing how responses differ between ecosystems and governance regimes, we will develop a typology of approaches that can be employed at multiple decision-making scales to enhance resilience to climate variability and change.

This workshop will bring together scientists and practitioners from different regions of the world to document and compare how marine fisheries are responding to the impacts of climate change. We are especially interested in comparing the response of fisheries in the northwest Atlantic, Norwegian-Barents Sea, Gulf of Alaska, and Australia, four regions that have experienced rapid environmental changes but have very different fisheries and fishery management systems. Within each region, we will outline the major climate impacts on fisheries and the responses to these impacts at different scales (*e.g.*, temporal, spatial, and social/institutional). The rationale behind selection of specific approaches and tools for climate adaptation will be discussed in the context of constraints and opportunities that exist within ecological, social, and governance systems of different regions. Specific objectives of the workshop include:

1. identifying climate adaptation measures that are being pursued in marine fisheries,
2. assessing conditions that constrain or facilitate adaptive actions, and
3. comparing how adaptation responses and options vary across ecosystems, fisheries, and management regimes.

The workshop will include a combination of invited talks that provide an overview of climate impacts, adaptation measures, and the fisheries context in each region and breakout groups to explore similarities and differences among regions in adaptation approaches for fisheries. A working group session will draft a framework for comparative analysis of climate adaptation initiatives in marine fisheries across regions and populate elements of this framework with information from each region. These results will be published in a journal manuscript.

Saturday, March 21, Day 1 (08:55-18:00)

08:55 ***Introduction by Convenors***

09:00 ***Introduction of participants***

09:15 **Katherine E. Mills and Andrew J. Pershing**
Cross-scale interactions in coupled social-ecological systems: An organizing framework for assessing climate impacts and adaptation in marine fisheries (W5-10091)

09:30 **Manuel Barange, J. Scholtens, Edward H. Allison, Gorka Merino, Julia L. Blanchard, James Harle, J. Icarus Allen, Jason Holt and S. Jennings (Invited)**
Combining cause and effect: Impacts of climate change on global fisheries and consequences for the dependency of nations on fisheries (W5-9983)

09:50 **Marcus Haward**
Governance and climate adaptation in marine fisheries: Social and institutional dimensions (W5-9835)

10:05 **Gretta Pecl, Stewart Frusher, Alistair J. Hobday, Sarah Jennings, Emily Ogier, Andrew Sullivan and Tim Ward**
Developing adaptation pathways for climate-impacted and at risk fisheries in south-east Australia (W5-10104)

10:20 **Wendy Morrison, Roger Griffis, Jon Hare, Valerie Termini and Mark Nelson**
Managing United States fisheries in a changing climate (W5-10080)

10:35 ***Coffee/Tea Break***

11:00 **Éva E. Plagányi, Ingrid van Putten, Alistair J. Hobday, Olivier Thébaud, James Innes, Lilly Lim-Camacho, Ana Norman-López, Rodrigo H. Bustamante, Anna Farmery, Aysha Fleming, Stewart Frusher, Bridget Green, Eriko Hoshino, Sarah Jennings, Gretta Pecl, Sean Pascoe, Peggy Schrobback and Linda Thomas (Invited)**
A quantitative metric to identify critical elements within seafood supply networks under a changing climate (W5-9899)

11:20 **Jason S. Link, Roger Griffis and D. Shallin Busch (Invited)**
Some solutions for marine Ecosystem-based Fisheries Management in a changing climate (W5-9961)

11:40 **Jacquelynne R. King, R. Ian Perry, Jean-Baptiste Lecomte and Andrew Edwards**
Can we give good stock assessment advice in a changing climate? (W5-10090)

11:55 **Anne B. Hollowed and Cody Szuwalski**
Setting biological reference points under a changing climate (W5-10253)

12:10 **Discussion**

12:25 ***Lunch***

14:00 **Discussion**

15:40 ***Coffee/Tea Break***

16:10 **Introduction**

16:25 **Leif Nøttestad, Kjell R. Utne, Gudmundur J. Óskarsson, Sigurður Þ. Jónsson, Jan Arge Jacobsen, Øyvind Tangen, Valantine Anthonypillai, Jens Christian Holst, Teunis Jansen and Aril Slotte (Invited)**
Increased abundance and spatial expansion of Northeast Atlantic mackerel (*Scomber scombrus*) according to swept-area trawl surveys in the Northeast Atlantic 2007 to 2014 (W5-9884)

16:45 **Andrew J. Pershing, Katherine E. Mills, Christina Hernandez, Lisa Kerr and Graham Sherwood**
Slow management during rapid ecosystem change: How rapid warming drove the collapse of Gulf of Maine cod (W5-10170)

17:00 **Stewart Frusher, Gretta Pecl, Alistair J. Hobday and Gustaaf M. Hallegraeff**
Observed impacts and adaptation strategies for coastal fisheries in south-east Australia (W5-9992)

17:15 Poster summaries

17:30 Wrap-up discussions

17:45 Posters

18:00 Day 1 Workshop ends

Sunday, March 22, Day 2 (08:55-18:00)

08:55 ***Introduction by Convenors***

09:00 **John K. Pinnegar, Miranda C. Jones and Paul Buckley (Invited)**
Climate change and UK fisheries – Exploring adaptation actions, perceptions within the industry and the challenge presented by fish stocks that move across international boundaries (W5-9954)

09:20 **Alistair J. Hobday, Gretta Pecl and Stewart Frusher**
Observed and predicted impacts and adaptation strategies for pelagic fisheries in south-east Australia (W5-9904)

09:35 **Patrick Lehodey, Inna Senina, Simon Nicol, John Hampton and John Sibert**
Managing Pacific tuna stocks under strong fishing pressure and climate change impact (W5-10018)

09:50 **Alan Haynie**
What are the key challenges to climate change adaptation in Bering Sea and Aleutian Islands groundfish fisheries? (W5-10196)

10:05 **Chris Kennedy**
The role of institutional complexity, historical allocations, and changing demographics in management performance for a climate-changed ecosystem: Lessons from the US mid-Atlantic summer flounder fishery (W5-10081)

10:20 **Lisa Pfeiffer**
Adaptation to climate variation in a multispecies fishery: The West Coast groundfish trawl fishery (W5-10094)

10:35 ***Coffee/Tea Break***

11:00 **Malin L. Pinsky, Kevin St. Martin, Eli Fenichel, Bonnie McCay and Simon Levin**
Adaptations of fish and fishing communities to rapid climate velocities (W5-10176)

11:15 **Kirstin K. Holsman, Kerim Aydin, Jim Ianelli, Anne B. Hollowed, Alan Haynie, André E. Punt, Al Hermann, Nicholas A. Bond and Georgina Gibbson**
Reel change comes at a price: The future of Bering Sea (AK) fisheries under climate change (W5-9994)

11:30 **Discussion**

12:30 ***Lunch***

14:00 **Discussion**

15:45 ***Coffee/Tea Break***

16:15 **Discussion**

18:00 Workshop ends

Sunday, March 22

Workshop 1 W1

Addressing uncertainty in projecting climate change impacts in marine ecosystems

Co-Convenors:
Manuel Barange (Plymouth Marine Labs, UK)
William Cheung (University of British Columbia, Canada)
Brian MacKenzie (Technical University of Denmark, Denmark)
Mark R. Payne (Technical University of Denmark, Denmark)

Invited Speaker:
William Cheung (University of British Columbia, Canada)

Accurate projections of the impacts of climate change on marine ecosystems are a key prerequisite for the planning of adaptation strategies. However, the biological sciences, and their associated social and economic components, trail behind their physical counterparts in terms of the robustness, reliability and accuracy of their projections. In this workshop we propose to advance the current state of the art about how such projections can be made, and, to answer the question, "how confident are we of the robustness and usefulness of projections to inform climate change adaptation and mitigation strategies in the context of ecosystem-based management of marine resources?"

We encourage contributions from the scientific community addressing uncertainties in future fisheries and seafood production under climate change, with productivity, abundance, food-web structure and distribution of marine populations, species and communities as potential case studies. We also welcome contributions from other disciplines, particularly the physical and social sciences, including economics, that describe how uncertainty is acknowledged and handled, and what makes robust projections/predictions in these fields.

The primary output from the workshop will be a focused review paper synthesising the lessons learned from the workshop. We will synthesise the most promising of these approaches in the context of uncertainty and risk assessment to both assess the quality of impact projections, and improve confidence in predictions. Finally, we will highlight gaps in existing knowledge and identify future research needs to improve the projections of climate change impacts in marine systems.

The workshop will address the various types of uncertainties common in modelling (see below). Plenary talks are invited to, in the first instance, introduce these aspects and the associated key questions to a general audience. They will then be followed by focused discussions in subgroups centred on each of the uncertainty elements. A final, brief, summary session will pull the threads back together.

We ask that potential presenters shape their contribution in relation to the fundamental uncertainty inherent in all modelling tasks and their consequences for projecting climate change impacts. A suggested classification of uncertainty types is included in the following table: we encourage presenters to address at least one of these themes, although other related themes are also welcome. We urge presenters to include specific descriptions of the uncertainties they intend to address in their presentation, when they submit their abstracts. These themes will also form the basis for the discussion groups: all participants in the workshop are encouraged to come with their own ideas and opinions to contribute.

Sunday, March 22 (08:55-18:00)

08:55 ***Introduction by Convenors***

09:00 **William W.L. Cheung, Rebecca G. Asch, Thomas Frölicher, Miranda C. Jones, Malin L. Pinsky, Keith Rodgers, Ryan R. Rykaczewski, Jorge L. Sarmiento, Charles A. Stock and James R. Watson (Invited)**
Projecting changes to living marine resources in an uncertain future (W1-10142)

09:30 **Mark R. Payne**
A statistical approach to model structural-uncertainty (W1-10265)

09:50 **Brian R. MacKenzie and H.E. Markus Meier**
A downscaling investigation of multi-model uncertainty of hindcasted and projected regional temperatures (W1-10272)

10:10 **Cosimo Solidoro, Giorgio Bolzon, Gianpiero Cossarini and Paolo Lazzari**
Uncertainties of model based assessment of climate change impact on marine ecosystems (W1-10062)

10:30 ***Coffee/Tea Break***

11:00 **Philipp Neubauer and Olaf P. Jensen**
Estimating variability and uncertainty in predatory relationships: A unified Bayesian framework for stable isotopes and fatty acid profiles (W1-10279)

11:20 **Ana M. Queirós, José A. Fernandes, William W.L. Cheung, Manuel Barange and Stephen Widdicombe**
Scaling up experimental climate change research: From individuals to the ecosystem (W1-9909)

11:40 **Lauge B. Rasmussen and Mette S. Hansen**
Ballast water management that adapts to climate changes and reduces harmful bio-invasions in marine eco-systems (W1-9921)

12:00 **Manuel Barange, Christian Mullon and José A. Fernandes**
Dealing with uncertainty when developing socio-economic scenarios for North Atlantic fisheries futures (W1-10271)

12:30 ***Lunch***

13:15 Group discussion and break-out groups

15:40 ***Coffee/Tea Break***

16:10 Group discussion and paper preparation

18:00 Workshop ends

Monday, March 23
Plenary

Plenary Session, Day 1

08:45 Opening Ceremony

09:15 **Chris Field (Keynote)**
Mapping the problem space and the opportunity space

10:15 ***Coffee/Tea Break***

10:45 **Arne Biastoch**
The potential of nested ocean modeling (S4-10009)

11:20 **Margareth Copertino**
Blue carbon ecosystems from South America: The role on carbon sequestration and mitigation of climate changes (S5-10242)
[Session 5 description p.220]

11:55 **Lynda E. Chambers, Peter Dann and Alistair J. Hobday**
Phenology responses of southern marine species to climate: Impacts and adaptation options (S6-10001)

12:30 Day 1 Plenary Session ends

Monday, March 23

Session 4 S4

Regional models for predictions of climate change impacts: Methods, uncertainties and challenges

Co-Convenors:
Shoshiro Minobe (Hokkaido University, Japan)
Enrique N. Curchitser (Institute of Marine and Coastal Science, Rutgers University, USA)

Invited Speaker:
Shin-ichi Ito (FRA, Japan)

Predicting climate change impacts on regional ocean processes and marine ecosystems is challenging because it (1) involves advanced and high-resolution models for the ocean and its resources, (2) has concrete consequences in terms of regional and national management of ecosystem services, and (3) aims to provide direct scientific support in the implementation of the Ecosystem Approach to Fisheries Management. A number of practical and conceptual challenges occurring at the regional scale will be highlighted in this session.

First, regional projections are subject to uncertainties that arise from the baseline global climate projections, the downstream modelling tools and in combining models. Regional models (RM), including regional air-sea coupled models or regional ocean models, are the starting points for understanding and projecting climate change on a regional scale. While global climate models are capable of capturing the large-scale mean climate behavior, they have limitations for regional assessments due to their coarse spatial resolutions. We welcome papers addressing the downscaling of global climate models to regional scale, including a variety of methods, both statistical and dynamical, such as high-resolution regional ocean circulation models with embedded biogeochemical models, and statistical models relating local population statistics to climate forcing or climate indices.

Secondly, expanding the RM projections to predicting climate change impacts on regional ecosystems in combination with other drivers such as fishing, requires the integration of ecosystem processes and knowledge on the ecosystem functioning, though a combination of multiple models. The use of multiple models can be three fold: (1) using several multidisciplinary models to build end-to-end models from the physics to the high trophic levels and their exploitation; (2) using multiple models to address uncertainty of the projections due to model structure and processes (*e.g.*, envelope approach, or comparative approach across models); and (3) using multiple hybrid approaches to integrate most of available information and data such as combination of climate statistical niche models and foodweb models. We welcome papers addressing the challenges and uncertainties in combining multiple models for regional global change impacts on ecosystems, and provide the opportunity for papers that combine different modelling approaches in order to improve the projections of global change, including climate change in combination with other stressors such as fishing and pollution.

Monday, March 23 (13:55-18:00)

13:55 ***Introduction by Convenors***

14:00 **Shin-ichi Ito, Takeshi Okunishi, Taketo Hashioka, Takashi T. Sakamoto, Naoki Yoshie, Kosei Komatsu and Akinori Takasuka (Invited)**
Regional models for projections of climate change impacts on small pelagic fishes in the western North Pacific (S4-10013)

14:30 **Charles A. Stock, John P. Dunne and Jasmin G. John**
Trophic amplification of ocean productivity trends in a changing climate (S4-9977)

14:50 **Edson J.R. Pereira and Ilana Wainer**
Downscaling the 1990-2100 ocean climate projections for the Arabian Gulf (S4-9805)

15:10 **Angelica Peña, Diane Masson and Mike Foreman**
A regional biogeochemical climate model for the British Columbia continental shelf (S4-10087)

15:30 ***Coffee/Tea Break***

16:00 **Rodrigo S. Martins**
Reviewing the use of computer-based modelling to study squid larval dispersal: Experiences from South Africa and Brazil (S4-10206)

16:20 **Illarion Mironov and Alexander Demidov**
Comparison numerical models results and hydrographic data in the Atlantic Ocean (S4-9886)

16:40 **Jonathan Tinker, Jason Lowe, Jason Holt and Rosa Barciela**
Marine climate projections for the NW European shelf seas: Dynamically downscaling a perturbed physics ensemble to explore climate uncertainty and temporal response (S4-10028)

17:00 **Ivonne Ortiz, Kerim Aydin and Al Hermann**
Fish movement and distribution drivers in a climate to fisheries model for the Bering Sea (S4-10238)

17:20 **Tarumay Ghoshal and Arun Chakraborty**
ROMS hindcast experiments on BOB's extreme events with daily forcing input (S4-9908)

17:40 **Fedor N. Gippius, Alisa Yu. Medvedeva, Elena A. Malyarenko, Victor S. Arkhipkin, Stanislav A. Myslenkov and Galina V. Surkova**
Wind wave regime of eastern European seas (S4-10037)

18:00 Session ends

Monday, March 23

Session 6

S6

Climate change in the seasonal domain: Impacts on the phenology of marine ecosystems and their consequences

Co-Convenors:
Mark Payne (Technical University of Denmark, Denmark)
Rubao Ji (Woods Hole Oceanographic Institution, USA)

Invited Speaker:
Sanae Chiba (Japan Agency for Marine-Earth Science and Technology, Japan)

The impacts of climate change on the timing of seasonal events (phenology) is well documented in terrestrial ecosystems. However, the challenges associated with observing life in the ocean have greatly limited our ability to understand the corresponding impacts on marine ecosystems. Nevertheless, changes in phenology in the ocean are inevitable and can potentially have consequences across multiple trophic levels (*e.g.*, via the match-mismatch hypothesis). This session will: (1) enable new results to be presented across multiple trophic levels; (2) allow researchers to exchange methods to study phenology based on limited marine data sets; and (3) attempt to draw together our understanding of climate change impacts in the seasonal domain.

Monday, March 23 (13:55-18:00)

13:55 ***Introduction by Convenors***

14:00 **Sanae Chiba, Mitsuhiro Toratani, Sayaka Yasunaka, Taketo Hashioka, Sonia Batten and Hiroya Sugisaki (Invited)**
Timing is everything? – Climate control on the North Pacific ecosystem phenology (S6-10019)

14:30 **Michael T. Burrows, Jorge García Molinos, Benjamin S. Halpern, Anthony J. Richardson, Pippa Moore, Elvira Poloczanska and David S. Schoeman**
Velocity and seasonal shift in climate: Ecologically relevant indices for predicting changes in species distributions and phenology (S6-9924)

14:50 **Anne Goffart, Amandine Collignon and Jean-Henri Hecq**
Control of plankton phenology by climate variation in a Mediterranean coastal area: Results from a long-term study (1979-2011) (S6-9944)

15:10 **Rubao Ji, Yun Li, Stephanie Jenouvrier, Meibing Jin, Julienne Stroeve, Garrett Campbell and Øystein Varpe**
Spatio-temporal variability of synchronicity between ice retreat and phytoplankton blooms in the polar regions (S6-9997)

15:30 ***Coffee/Tea Break***

16:00 **Inga Kristiansen, Eilif Gaard, Høgni Debes, Bogi Hansen and Sigrún Jónasdóttir**
Diversity and phenology changes of *Calanus* in the south-western Norwegian Sea, 1990-2014, linked to ocean climate (S6-9871)

16:20 **Clément LeGoff, Yves-Marie Paulet, Aurélie Jolivet, Ronan Fablet, Stéphane Pouvreau, Bertrand Chaperon and Christophe Cassous**
From large scale climate variability to individual character changes in coastal invertebrates: The case of NAO and of the daily growth of the scallop, *Pecten maximus* (S6-10252)

16:40 **Andrew J. Pershing, Katherine E. Mills, Nicholas R. Record, and Christina Hernandez**
Seasonal forecasts for the timing of lobster landings (S6-10208)

17:00 **Jennifer I. Fincham, Georg H. Engelhard and Adriaan D. Rijnsdorp**
Warmer winters and shifting spawning phenology in sole (S6-9856)

17:20 **Anna B. Neuheimer, Mark R. Payne and Brian R. MacKenzie**
The roles of plasticity and adaptation in spawning time of Atlantic cod (*Gadus morhua*): Explaining phenology and making predictions in a changing climate (S6-10082)

17:40 **Rebecca G. Asch, Charles A. Stock and Jorge L. Sarmiento**
Projected mismatches between the phenology of phytoplankton blooms and fish spawning based on the GFDL Earth System Model (ESM2M) (S6-10086)

18:00 Session ends

Tuesday, March 24

Plenary

Plenary Session, Day 2

09:00 **Paulo H.R. Calil**
Multi-scale physical-biological interactions in the ocean – The importance of submesoscale processes (S1-10000)

09:35 **Patrick Lehodey, Inna Senina, Simon Nicol, John Hampton, Anna Conchon, Anne-Cecile Dragon, Olivier Titaud, Beatriz Calmettes, Olivier Aumont, Morgane Dessert, Thomas Gorgues and Christophe Menkes**
Forecasting climate change impacts on large pelagic fish populations and fisheries: Progress, uncertainties and research needs (S10-9907)

10:10 **Laura J. Richards, Robin M. Brown, James Christian and Jake Rice**
Looking back to go forward: Do past management actions foreshadow management responses to climate change? (S12-10002)

10:45 Day 2 Plenary Session ends

Tuesday, March 24

Session 1 S1

Role of advection and mixing in ocean biogeochemistry and marine ecosystems

Co-Convenors:
Fei Chai (University of Maine, USA)
Fangli Qiao (First Institute of Oceanography, SOA, PR China)

Invited Speaker:
Alexander Babanin (Swinburne University of Technology, Australia)

Both horizontal and vertical advection and mixing are among the most fundamental physical processes for ocean biogeochemistry and marine ecosystems. Well-defined currents, upwelling, meso- and submeso-scale eddies and mixing control the transport and budget of a wide range of physical, biogeochemical, and biological properties (*e.g.*, heat, nutrients, oxygen, dissolved carbon, plankton, fish eggs, and larvae). However, these transports and budgets are often not well understood, even under current climate conditions. Global climate change influences ocean biogeochemistry and marine ecosystems through changes in currents, eddy characteristics, mixing and associated wind-driven and thermohaline circulation. In particular, enhanced surface stratification is expected to produce weaker mixing between the surface layer and depth leading to reduction of primary production, and weakened ventilation can accelerate ocean deoxygenation and acidification at depth. This session welcomes studies that investigate advection, eddies and mixing in the physical fields and their implications for biogeochemistry and marine ecosystems under current and future climate conditions.

Tuesday, March 24 (11:15-18:10)

11:15 ***Introduction by Convenors***

11:20 **Alexander V. Babanin (Invited)**
Wave-induced turbulence: Theory and practice (S1-10136)

11:50 **Huijie Xue, Ango Hsu and Fei Chai**
Variability of the North Equatorial Current (NEC) and its implications on Japanese eel larval transport (S1-10143)

12:10 **Julien Palmiéri, Andrew Yool and Ekaterina Popova**
Temporal evolution of marine biogeochemistry in Large Marine Ecosystems (S1-10048)

12:30 ***Lunch***

14:00 **Fangli Qiao and Zhenya Song**
The fundamental role of the surface wave in the ocean and climate systems (S1-9854)

14:20 **Xuanliang Ji, Guimei Liu and Shan Gao**
Temporal and spatial variability of carbon cycle in the northwestern Pacific Ocean: A three-dimensional physical-biogeochemical modeling study (S1-9881)

14:40 **Eliana Gómez Ocampo, Emilio Beier, Gilberto Gaxiola-Castro and Mario A. Pardo**
Effects of dynamical processes on primary production and phytoplankton biomass in the Pacific subtropical-tropical zone (S1-10084)

15:00 **Sólvá Káradóttir Eliasen, Bogi Hansen, Karin Margretha Húsgarð Larsen and Hjálmar Hátún**
How does horizontal mixing affect the primary production on the Faroe Shelf? (S1-9920)

15:20 **Vibe Schourup-Kristensen, Judith Hauck, Dieter A. Wolf-Gladrow and Christoph Völker**
Iron supply to the Southern Ocean mixed layer from below: The ocean model effect (S1-10035)

15:40 ***Coffee/Tea Break***

16:10 **Fei Chai, Huijie Xue, Peng Xiu and Mingxian Guo**
Modeling impacts of mesoscale eddies on biogeochemical processes in the South China Sea (S1-10130)

16:30 **Andrew Yool, Ekaterina Popova, Julien Palmiéri and Andrew C. Coward**
Future change in ocean productivity: Is the Arctic the new Atlantic? (S1-10046)

16:50 **Karina Kammer Attisano, Isaac Rodrigues Santos, Carlos F.F. de Andrade, Mariele Lopes de Paiva, Idel Cristina Bigliardi Milani and Luis Felipe Hax Niencheski**
Submarine Groundwater Discharge revealed by radium isotopes (Ra-223 and Ra-224) near a paleochannel on the Southern Brazilian continental shelf (S1-10077)

17:10 **Josie Robinson, Ekaterina Popova, Meric Srokosz and Andrew Yool**
To what extent does iron advection affect the inter-annual variability of Southern Ocean island blooms? (S1-10078)

17:30 **Shin-ichi Ito, Taku Wagawa, Shigeho Kakehi, Takeshi Okunishi and Daisuke Hasegawa**
Importance of advection to form a climate and ecological hotspot in the western North Pacific (S1-10015)

17:50 **Bin Xiao, Fangli Qiao and Qi Shu**
The performance of a z-level ocean model in modeling global tide (S1-9911)

18:10 Session ends

Tuesday, March 24

Session 10, Day 1 S10

Forecasting climate change impacts on fish populations and fisheries

Co-Convenors:
Alistair Hobday (CSIRO, Australia)
Anne Hollowed (Alaska Fisheries Science Centre, National Marine Fisheries Service, USA)

Invited Speakers:
V. Kripa (CMFRI, India)
Elvira Poloczanska (CSIRO, Australia)

Climate change is a major driver affecting the productivity of key species in global fisheries. This session encourages papers that focus on identifying the mechanisms and forecasting the impact of climate change on the productivity and distribution of important marine species that sustain global or regional fisheries. Papers identifying the mechanisms that link climate to fish productivity or distribution will be considered. The session will focus on model projections of regional future climate and physical oceanographic scenarios linked to fish population dynamics. These linkages can include changes in biogeochemical processes, phytoplankton and zooplankton communities, or ecologically important fish species. The linkages can be made by statistical and mechanistic approaches from a range of models including mass-balance, sized-based, individual-based and end-to-end models. Additional topics of interest include responses of fisheries management systems, and the interaction between climate and harvest impacts on fish populations.

Tuesday, Day 1, March 24 (11:15-18:00)

11:15 ***Introduction by Convenors***

11:20 **Elvira Poloczanska (Invited)**
Climate change effects on fish and fisheries (S10-10039)

11:50 **Joana Boavida-Portugal, José R. Paula, François Guilhaumon, Miguel B. Araújo and Rui Rosa**
Small pelagics and climate change (S10-10222)

12:10 **Paul D. Spencer, Nicholas A. Bond, Anne B. Hollowed, Stephani Zador, Kirstin Holsman and Franz J. Mueter**
How might environmentally-driven changes in the distribution of arrowtooth flounder affect eastern Bering Sea walleye pollock predation mortality and population projections? (S10-10050)

12:30 ***Lunch***

14:00 **Irene Alabia, Sei-Ichi Saitoh, Hiromichi Igarashi, Yoichi Ishikawa, Norihisa Usui, Masafumi Kamachi, Toshiyuki Awaji and Masaki Seito**
Potential climate impacts of ocean warming to squid inferred habitat in North Pacific: Implications on future resource availability (S10-9918)

14:20 **Louise A. Rutterford, Stephen D. Simpson, Simon Jennings, Mark P. Johnson, Julia L. Blanchard, Pieter-Jan Schön, David W. Sims, Jonathan Tinker and Martin J. Genner**
Future fish distributions constrained by depth in warming seas (S10-10027)

14:40 **Abigail Marshall, John K. Pinnegar and Julia L. Blanchard**
How do alternative models of individual growth affect size-structured population and community responses to climate change and fishing? (S10-10190)

15:00 **Nick Caputi, Ainslie Denham, M. Kangas, Ming Feng, Alan Pearce, Y. Hetzel and A. Chandrapavan**
The effect of an extreme marine heat wave on invertebrate fisheries in Western Australia (S10-9827)

15:20 **Jean-Baptiste Lecomte, Jacquelynne R. King and Andrew M. Edwards**
Linking climate variability to rockfish recruitment (S10-10232)

15:40 ***Coffee/Tea Break***

16:10 **V. Kripa, E. Vivekanandan, P.U. Zacharia and Ayyaru Gopalakrishnan (Invited)**
Climate change influences on India's marine fisheries (S10-10263)

16:40 **José A. Fernandes, S. Kay, M.A.R. Hossain, M. Ahmed, William W.L. Cheung and Manuel Barange**
Modelling fish production in Bangladesh under environmental change and socio-economic scenarios (S10-9824)

17:00 **Georg H. Engelhard, John K. Pinnegar and Ewan Hunter**
What the world's longest fish size time-series can tell us about climate change, fishing, eutrophication and war: North Sea plaice, 1902 to now (S10-9857)

17:20 **Tyler D. Eddy, Christopher E. Cornwall, Laurent Bopp, Tilla Roy, Beth Fulton and Heike K. Lotze**
Effects of near-future climate change, fishing, and marine protection on a temperate, coastal ecosystem (S10-9873)

17:40 **Alan Haynie and Lisa Pfeiffer**
Predicting how climate variation affects the Bering Sea pollock trawl and Pacific cod longline fisheries (S10-10228)

18:00 Day 1 Session ends

Tuesday, March 24

Session 12 S12

Linking climate change to marine management objectives

Co-Convenors:
Jacquelynne R. King (Pacific Biological Station, Fisheries and Oceans Canada, Canada)
Alexander Turra (Oceanographic Institute, São Paulo University, Brazil)

Invited Speaker:
Kao Sochivi (Fisheries Administration, Cambodia)

Marine ecosystems are subject to a number of stressors, such as pollution, resource exploitation, coastal development, marine infrastructures and transport. Historically, management objectives have focused on addressing individual stressors, disregarding their often synergistic and compounding effects. The application of the ecosystem approach to management has reversed this trend and has encouraged more holistic and cross-sectorial management objectives. Climate change is expected to affect many of these stressors as well as the responses of marine ecosystems to them. This session will consider single as well as cross-sectoral management applications to address the effects of climate change on marine ecosystems in the context of expected climate change impacts, such as changes in productivity and seasonality of resources. The session will also consider the combined effects of climate change with other direct stressors (such as pollution) and how they interact with fisheries and ecosystem management scenarios.

Tuesday, March 24 (11:15-17:30)

11:15 ***Introduction by Convenors***

11:20 **Kao Sochivi (Invited)**
Fisheries management and climate change responses in Cambodia (S12-10261)

11:50 **Jake Rice**
Managing in times of transition: How policy and management should react to climate change (S12-10256)

12:10 **Marcus Haward**
Governance challenges for marine climate hotspots (S12-9546)

12:30 ***Lunch***

14:00 **Leo X.C. Dutra and Marcus Haward**
Institutional and organizational mapping – A powerful approach to identify opportunities and constraints for climate adaptation in fast warming regions (S12-9863)

14:20 **Linus Hammar**
Effects of climate change on the world's oceans are not important in current marine management (S12-10069)

14:40 **Débora De Freitas, Laura Stocker and Richard Kenchington**
Uptake and pathways of coastal adaptation processes in Australia (S12-9998)

15:00 **Lucy M. Robinson, Martin P. Marzloff, Sarah Jennings, Stewart Frusher, Sam Nicol, Gretta Pecl, Ingrid van Putten, Alistair J. Hobday, Marcus Haward, Sean Tracey and Klaas Hartmann**
Informing ecosystem-based management of the range extending long-spined sea urchin using a structured decision making process (S12-10159)

15:20 **Thomas G. Safford, Megan Henly and Michelle Renk**
Climate change, science, and mariculture management in the United States and Brazil (S12-10040)

15:40 ***Coffee/Tea Break***

16:10 **Christopher Lynam and Steven Mackinson**
Mixed fisheries and ecosystem based management: Trade-offs and the importance of climate (S12-9893)

16:30 **Stefan Koenigstein and Stefan Goessling-Reisemann**
Model-based integration of experimental results and human uses to identify management options for marine ecosystems under climate change (S12-9963)

16:50 **Ana M. Queirós and Stephen Widdicombe**
Carbon capture and storage impacts on marine systems: Are local impacts good return for global mitigation? (S12-9790)

17:10 **Thamasak Yeemin, Watchara Samsuvan, Kanwara Sangmanee, Juthamart Putthayakool, Montaphat Thummasan, Mathinee Yucharoen and Makamas Sutthacheep**
Impact of coral bleaching events and adaptive management of tourism in the Thai waters (S12-9965)

17:30 Session ends

Wednesday, March 25

Plenary

Plenary Session, Day 3

09:00	**Jean-Pierre Gattuso** Ocean acidification: Knowns, unknowns and perspectives (S2-9859)
09:35	**Lisa A. Levin** Biodiversity consequences of climate change in the deep ocean (S8-9890)
10:10	**Edward H. Allison** From climate physics to coastal people: What do we know about climate change and its potential impacts on coastal populations? (S11-10244)
10:45	Day 3 Plenary Session ends

Wednesday, March 25

Session 2, Day 1 S2

Ocean acidification

Co-Convenors:
Nicholas Bates (Bermuda Institute of Ocean Sciences, Bermuda/USA)
Silvana Birchenough (The Centre for the Environment Fisheries and Aquaculture Science Laboratory, UK)

Invited Speakers:
Ruy Kenji P. Kikuchi (Geosciences Institute, Federal University of Bahia, Brazil)
Nelson Lagos (Universidad Santo Tomás, Chile)

A major change in ocean biogeochemistry is the acidification of global oceans. This change is occurring in concert with climate change since it is mainly due to increased CO_2 rather than warming. Though persistent trends in carbon, pH, and ocean acidification exist, quantitative knowledge is still progressing toward a complete picture of the devastating effects of acidification on a wide range of marine organisms, particularly those that build shells and skeletons from calcium carbonate. This session encourages submissions that discuss: (1) historical and future trends in the marine carbon cycle, ocean acidification, and related ocean biogeochemistry; (2) anthropogenic drivers and climate change relationships with ocean acidification; (3) physico-biogeochemical impacts of ocean acidification on marine biogeochemistry and ecosystems; and (4) future challenges associated with understanding the role of climate change on the physico-biogeochemical impacts of ocean acidification, including consideration of ocean deoxygenation and greater stagnation associated with a slowdown in ocean circulation which may result in an acceleration of acidification.

Wednesday, Day 1, March 25 (11:15-18:10)

11:15 ***Introduction by Convenors***

11:20 **Ruy Kenji P. Kikuchi (Invited)**
Progress and prospects on ocean acidification research of the Tropical South Atlantic (S2-10075)

11:50 **Aziz ur Rahman Shaik, Haimanti Biswas and Debasmita Bandyopadhyay**
Effective CO_2 utilization in response to increasing CO_2 levels in natural phytoplankton assemblages from the coastal Bay of Bengal, India (S2-9866)

12:10 **Markus Weinbauer, Chiaki Motegi, Jinwen Liu, Cornelia Maier, Maria-Luiza Pedrotti, Minhan Dai and Jean-Pierre Gattuso**
Effects of elevated pCO_2 and temperature on prokaryotic community composition and respiration in mesopelagic waters of the NW Mediterranean Sea (S2-9943)

12:30 ***Lunch***

14:00 **Marius N. Müller, Joana Barcelos e Ramos, Kai G. Schulz, Ulf Riebesell, Jozef Kazmierczak and Gustaaf M. Hallegraeff**
Coccolithophores, calcification and ocean acidification (S2-9789)

14:20 **Suchana Chavanich, Wipada Lalitpattarakit, Narainrit Chinfak, Suppakarn Jandang, Pataporn Kuanui, Somkiat Khokiattiwong and Voranop Viyakarn**
pH monitoring in the upper Gulf of Thailand and effect on early development and settlement of corals, *Acropora millepora* and *Pocillopora damicornis* (S2-10266)

14:40 **Anna K. McLaskey, Julie E. Keister, Paul McElhany, M. Brady Olson, Brooke A. Love, Amanda K. Winans, D. Shallin Busch and Mike Maher**
Effects of ocean acidification on crustacean zooplankton: A comparison of the copepod *Calanus pacificus* and the krill *Euphausia pacifica* (S2-10139)

15:00 **Adam Sokołowski, Dominika Brulińska and Zuzanna Mirny**
Behavioural and physiological responses of the estuarine bivalve *Macoma balthica* from the Baltic Sea to increased CO_2 concentration (S2-9885)

15:20 **Anthony Moreira, Etelvina Figueira, Ângela Almeida, Iracy L. Pecora, Amadeu M.V.M. Soares and Rosa Freitas**
Combined effects of seawater acidification and Arsenic in *Crassostrea gigas* and *C. angulata*: Oxidative stress and biomineralization enzymes activity assessment (S2-9989)

15:40 ***Coffee/Tea Break***

16:10 **Sue-Ann Watson, Blake L. Spady, Sjannie Lefevre, Paolo Domenici, Göran E. Nilsson and Philip L. Munday**
Ocean acidification alters marine invertebrate behaviour via neural impairment (S2-10158)

16:30 **Megan J. Welch, Sue-Ann Watson, Justin Q. Welsh, Mark I. McCormick and Philip L. Munday**
Effects of elevated CO_2 on fish behaviour undiminished by transgenerational acclimation (S2-9815)

16:50 **Ellie Bergstrom, Marina Nasri Sissini and Paulo Horta**
Effects of ocean acidification and global warming on the physiological ecology of rhodoliths (Rhodophyta) and seagrass (S2-10241)

17:10 **Marta S. Pimentel, Filipa Faleiro, Jorge Machado, Myron A. Peck, Hans Pörtner and Rui Rosa**
The effect of ocean warming and acidification on the aerobic and anaerobic metabolic potential of fish early life stages (S2-10185)

17:30 **Tullio Rossi, Ivan Nagelkerken, Jennifer C.A. Pistevos, Stephen D. Simpson, Sue-Ann Watson, Philip L. Munday, P. Fraser and Sean D. Connell**
Ocean acidification causes disorientation in fish larvae during critical settlement stage (S2-10137)

17:50 **Rui Rosa, José R. Paula, Miguel Baptista, Vanessa M. Lopes, Katja Trübenbach, Marta S. Pimentel, Ricardo Calado and Tiago Repolho**
Ecophysiology of shark early stages under climate change (S2-10131)

18:10 Day 1 Session ends

Wednesday, March 25

Session 8, Day 1 S8

Climate change impacts on marine biodiversity and resilience

Co-Convenors:
Patricia Miloslavich (Universidad Simon Bolivar, Venezuela)
Jake Rice (Fisheries and Oceans Canada, Canada)

Invited Speaker:
Camilo Mora (University of Hawaii, USA)

Biodiversity is often viewed as an ecosystem characteristic of a healthy environment that enables resilience to perturbations. Climate change can impact community composition resulting in loss of habitat, timing of life cycle events, changes in species distribution that either removes a species from the system or introduces a new species. These impacts affect the function and structure of regional marine ecosystems on various spatial and temporal scales. Climate variability is projected to change the magnitude and frequency of extreme events such that marine ecosystems may be pushed to a tipping point beyond which new processes and structures may emerge. This session encourages papers that investigate observed and predicted impacts of climate change and variability on marine biodiversity and regional ecosystem resilience.

Wednesday, Day 1, March 25 (11:15-18:10)

11:15 ***Introduction by Convenors***

11:20 **Camilo Mora (Invited)**
We punch nature and it will punch us back: Human impacts on marine biodiversity and their feedbacks (S8-10262)

11:50 **Giulia Ghedini, Bayden D. Russell and Sean D. Connell**
Contrasting effects of sustained warming and heat waves on ecosystem resilience: Climate variability disrupts producer-consumer relationships decreasing resilience to multiple disturbances (S8-9787)

12:10 **Inês Leal, Vanessa Mendonça, Diana Madeira, Luís Narciso, Mário S. Diniz, Augusto A.V. Flores and Catarina Vinagre**
Acclimation capacity of tropical and temperate coastal organisms (S8-9831)

12:30 ***Lunch***

14:00 **Stephanie A. Henson, Claudie Beaulieu and Jorge L. Sarmiento**
Rapid emergence of marine ecosystem stress (S8-9880)

14:20 **Éva E. Plagányi, Timothy Skewes and Alistair J. Hobday**
Modelling ecological tipping points and road-testing management strategies for increasing marine ecosystem resilience (S8-9898)

14:40 **Miranda C. Jones and William W.L. Cheung**
Assessing vulnerability of marine species to climate change in the world's oceans: Combining biological traits, climate projections and species distribution modelling (S8-9929)

15:00 **Laura J. Falkenberg, Bayden D. Russell and Sean D. Connell**
The role of species interactions in determining ecosystem resistance to an increasingly modified world (S8-9931)

15:20 **Ryan D. Batt and Malin L. Pinsky**
Impacts of climate on marine community structure across North America (S8-10213)

15:40 ***Coffee/Tea Break***

16:10 **Claudie Beaulieu, Renata Stella Khouri, Harriet Cole, Stephanie A. Henson and Andrew Yool**
Marine regime shift detection and attribution (S8-10059)

16:30 **Laurène Pécuchet, Martin Lindegren, Anna Törnroos and Mark R. Payne**
Environmental pressure drives functional diversity of fish assemblages in a temperate brackish system (S8-10161)

16:50 **Katherine E. Mills, Andrew J. Pershing and Arnault Le Bris**
Size structure, diversity and resilience: Observations and predictions in the context of climate change (S8-10096)

17:10 **Denilson da Silva Bezerra, Silvana Amaral, Milton Kampel, Eduardo Rodrigues and Fabricio Brito Silva**
Modeling of the pattern of mangrove resistance to sea-level rise (S8-9803)

17:30 **Pedro C. González-Espinosa, David A. Paz-García, Eduardo F. Balart and Héctor Reyes-Bonilla**
Extreme events of cold water and high light irradiance are responsible of massive bleaching in coral reefs (S8-10112)

17:50 **Martin P. Marzloff, Katell Hamon, Eriko Hoshino, Sarah Jennings, Jessica Melbourne-Thomas, Ingrid van Putten and Gretta Pecl**
Ecological impacts of species range shifts: Identifying the good, the bad and the uncertain (S8-10031)

18:10 Day 1 Session ends

Wednesday, March 25

Session 11 S11

Impacts on coastal communities

Co-Convenors:
Eddie Allison (School of Marine and Environmental Affairs, University of Washington, USA)
Manuel Barange (Plymouth Marine Laboratory, UK)

Invited Speaker:
Nesar Ahmed (Bangladesh Agricultural University, Bangladesh)

By their proximity to the ocean, coastal communities naturally rely on ecosystem services provided by marine systems. The extent of this reliance, or the type of services relied on, will vary from region to region. Climate change impacts on ecosystems will alter ecosystem services, with both negative and positive alterations. Additionally, there will be direct climate change impacts on coastal communities due to such factors as sea level rise, storm intensity or frequency, wave dynamics, and coastal erosion. This session will focus on the impacts of climate change on coastal communities due to alteration in ecosystem services or direct physical stressors, attempting to quantify the vulnerability of coastal communities to climate change. Papers that outline ecosystem and adaptive management for mitigation are encouraged.

Wednesday, March 25 (11:15-18:10)

11:15 ***Introduction by Convenors***

11:20 **Nesar Ahmed (Invited)**
Climate change vulnerability and adaptation in the low-lying tropics: The case of shrimp farming in coastal Bangladesh (S11-9939)

11:50 **Mohammad Mahmudul Islam**
Analyzing climate change impacts through social wellbeing lens: The case of Bangladesh coastal community (S11-9962)

12:10 **Sibananda Senapati**
Climate change and vulnerable communities: A study on coastal fisheries from India (S11-9816)

12:30 ***Lunch***

14:00 **William W.L. Cheung, Vicky W.Y. Lam, Miranda C. Jones, Dana Miller and U. Rashid Sumaila**
Transforming fisheries management to build climate-resilience in seafood security of coastal countries (S11-10141)

14:20 **Jenny Shaw, Laura Stocker and Nick Caputi**
Fishers adapting to change: A cascade of climate, environment, management, economic and social changes (S11-9973)

14:40 **James A.E. Howard, Shankar Aswani, Mary Gasalla, Sarah Jennings, Willem Malherbe, Ivan Martins, R. Narayanakuma, Shyam S. Salim, P.S. Swathilekshmi and Ingrid van Putten**
Social vulnerability of coastal communities to climate change: A Southern hemisphere comparison (S11-10129)

15:00 **Débora De Freitas, Wilson Cabral de Sousa Jr., Carlos Eduardo Nakao Inouye and Rafael de Oliveira Sakai**
Climate change impacts on coastal societies and infrastructure – Assessing risk against a changing population in the north coast of São Paulo, Brazil (S11-10099)

15:20 **Carla I. Elliff and Ruy Kenji P. Kikuchi**
Considerations on the potential of increase in coastal vulnerability in Tinharé and Boipeba Islands, Bahia, Brazil, in face of climate change (S11-10188)

15:40 ***Coffee/Tea Break***

16:10 **Shang Chen, Tao Xia, Yi Xiao and Zhiquan Cao**
Anthropogenic and climate effects on change of marine ecological capital (S11-9808)

16:30 **Fotis Psarros, Isavela Monioudi, Olympos Andreadis, Thomas Hasiotis, Adonis Velegrakis, Antonis Hatzipavlis, Vasilis Trygonis and Charalambos Dimitriadis**
Evaluation of climate change impacts on the sea-turtle nesting beaches of Zakynthos National Marine Park, Greece (S11-10073)

16:50 **Ingrid van Putten, Sarah J. Metcalf, Stewart Frusher, Nadine A. Marshall, Malcolm Tull, Nick Caputi, Marcus Haward, Alistair J. Hobday, Neil Holbrook, Sarah Jennings, Gretta Pecl and Jenny Shaw**
A marine climate change adaptation blueprint for coastal regional communities (S11-9995)

17:10 **Discussion**

18:10 Session ends

Thursday, March 26

Session 2, Day 2 S2

Ocean acidification

Co-Convenors:
Nicholas Bates (Bermuda Institute of Ocean Sciences, Bermuda/USA)
Silvana Birchenough (The Centre for the Environment Fisheries and Aquaculture Science Laboratory, UK)

Invited Speakers:
Ruy Kenji P. Kikuchi (Geosciences Institute, Federal University of Bahia, Brazil)
Nelson Lagos (Universidad Santo Tomás, Chile)

A major change in ocean biogeochemistry is the acidification of global oceans. This change is occurring in concert with climate change since it is mainly due to increased CO_2 rather than warming. Though persistent trends in carbon, pH, and ocean acidification exist, quantitative knowledge is still progressing toward a complete picture of the devastating effects of acidification on a wide range of marine organisms, particularly those that build shells and skeletons from calcium carbonate. This session encourages submissions that discuss: (1) historical and future trends in the marine carbon cycle, ocean acidification, and related ocean biogeochemistry; (2) anthropogenic drivers and climate change relationships with ocean acidification; (3) physico-biogeochemical impacts of ocean acidification on marine biogeochemistry and ecosystems; and (4) future challenges associated with understanding the role of climate change on the physico-biogeochemical impacts of ocean acidification, including consideration of ocean deoxygenation and greater stagnation associated with a slowdown in ocean circulation which may result in an acceleration of acidification.

Thursday, Day 2, March 26 (08:55-12:40)

08:55 ***Introduction by Convenors***

09:00 **Nelson Lagos, Marco Lardies, Bernardo Broitman, Stefan Gelcich, Felipe Vasquez and Cristián Vargas (Invited)**
Ocean acidification along the southeastern Pacific coastal ecosystems: Biological responses, interactions with multiple stressors and human dimensions (S2-10052)

09:30 **Julien Palmiéri, J.C. Orr, J.-C. Dutay, K. Béranger, A. Schneider, J. Beuvier and S. Somot**
Simulated anthropogenic CO_2 storage and acidification of the Mediterranean Sea (S2-10056)

09:50 **Eric Douville, Martine Paterne, Nathalie Feuillet, Claude Noury, Louise Bordier and François Thil**
A 200-year record of interannual pH and SST variability from the Lesser Antilles (Caribbean Sea) inferred from a *Siderastrea siderea* reef coral (S2-10223)

10:10 **Gisela Dionísio, Marta S. Pimentel, Sónia Cruz, Meri Bilan, Tiago Repolho, JoãoSerôdio, Ricardo Calado and Rui Rosa**
Climate change impacts on tropical and temperate photosynthetic sea slugs (S2-10122)

10:30 ***Coffee/Tea Break***

11:00 **Sean D. Connell**
The other ocean acidification problem: CO_2 as a resource among competitors for ecosystem dominance (S2-9892)

11:20 **John K. Pinnegar, Silvana Birchenough and Nick K. Dulvy**
Who are the most vulnerable? – A global assessment of exposure, sensitivity, adaptive capacity and vulnerability to ocean acidification (S2-10033)

11:40 **Uta Passow**
Ocean acidification, warming and the biological carbon pump (S2-9895)

12:00 **Denise Breitburg, Andrew Keppel, Seth Miller and Rebecca Burrell**
Climate change in the shallows – interacting effects of diel-cycling hypoxia and acidification (S2-10229)

12:20 **Sue-Ann Watson**
Giant clams and rising CO_2: Light may ameliorate effects of ocean acidification in a solar-powered animal (S2-10160)

12:40 Session ends

Thursday, March 26

Session 8, Day 2 S8

Climate change impacts on marine biodiversity and resilience

Co-Convenors:
Patricia Miloslavich (Universidad Simon Bolivar, Venezuela)
Jake Rice (Fisheries and Oceans Canada, Canada)

Invited Speaker:
Camilo Mora (University of Hawaii, USA)

Biodiversity is often viewed as an ecosystem characteristic of a healthy environment that enables resilience to perturbations. Climate change can impact community composition resulting in loss of habitat, timing of life cycle events, changes in species distribution that either removes a species from the system or introduces a new species. These impacts affect the function and structure of regional marine ecosystems on various spatial and temporal scales. Climate variability is projected to change the magnitude and frequency of extreme events such that marine ecosystems may be pushed to a tipping point beyond which new processes and structures may emerge. This session encourages papers that investigate observed and predicted impacts of climate change and variability on marine biodiversity and regional ecosystem resilience.

Thursday, Day 2, March 26 (08:55-12:30)

08:55 ***Introduction by Convenors***

09:00 **Alistair J. Hobday and Rachael Alderman**
Testing a climate adaptation strategy for vulnerable seabirds based on prioritisation of intervention options (S8-9901)

09:20 **Rodolfo Vögler, Francisco Arreguín-Sánchez, Diego Lercari, Pablo del Monte-Luna and Danilo Calliari**
Long-term climate variability effects on the trophodynamics of a South American temperate estuarine ecosystem (S8-9930)

09:40 **Angelo F. Bernardino, Sérgio Netto, Paulo R. Pagliosa, Francisco Barros, Ronaldo A. Christofoletti, Leonir A. Colling, Paulo C. Lana, José Souto R. Filho, Rafaela C. Maia and Tânia M. Costa**
Predicting ecological changes of benthic estuarine assemblages from Marine Ecoregions of Brazil through decadal climatology (S8-9980)

10:00 **Bayden D. Russell and Sean D. Connell**
Surviving in a warming world: Acclimation of molluscs to warming is dependent on ocean acidification and thermal variability (S8-10005)

10:20 **Elvira Poloczanska, Kristen Williams, Steve Crimp and Phil Kokic**
Future ecosystem states: Linking ecological responses to climatic extremes (S8-10038)

10:40 ***Coffee/Tea Break***

11:10 **Ivan Nagelkerken and Sean D. Connell**
Effects of ocean acidification on marine species (S8-10115)

11:30 **Ian McCarthy, Coleen Suckling, Melody Clark, Simon Morley and Lloyd Peck**
Antarctic sea urchins can acclimate within months to rapid climate change (S8-10269)

11:50 **Bryony L. Townhill, John K. Pinnegar and Miranda C. Jones**
Invasive, non-native and nuisance species and how climate change might contribute to their spread (S8-9829)

12:10 **Daniel J. Mayor, Ulf Sommer, Kathryn B. Cook and Mark R. Viant**
The metabolic response of marine copepods to environmental warming, ocean acidification and food deprivation (S8-10237)

12:30 Day 2 Session ends

Thursday, March 26

Session 10, Day 2 S10

Forecasting climate change impacts on fish populations and fisheries

Co-Convenors:
Alistair Hobday (CSIRO, Australia)
Anne Hollowed (Alaska Fisheries Science Centre, National Marine Fisheries Service, USA)

Invited Speakers:
V. Kripa (CMFRI, India)
Elvira Poloczanska (CSIRO, Australia)

Climate change is a major driver affecting the productivity of key species in global fisheries. This session encourages papers that focus on identifying the mechanisms and forecasting the impact of climate change on the productivity and distribution of important marine species that sustain global or regional fisheries. Papers identifying the mechanisms that link climate to fish productivity or distribution will be considered. The session will focus on model projections of regional future climate and physical oceanographic scenarios linked to fish population dynamics. These linkages can include changes in biogeochemical processes, phytoplankton and zooplankton communities, or ecologically important fish species. The linkages can be made by statistical and mechanistic approaches from a range of models including mass-balance, sized-based, individual-based and end-to-end models. Additional topics of interest include responses of fisheries management systems, and the interaction between climate and harvest impacts on fish populations.

Thursday, Day 2, March 26 (08:55-12:30)

08:55 ***Introduction by Convenors***

09:00 **Vicky W.Y. Lam, William W.L. Cheung and U. Rashid Sumaila**
Change in global fisheries economics with climate change (S10-9988)

09:20 **Christopher Lynam, Pierre HelaouetChristian Möllmann, Marcos Llope, Roddy Mavor, Georgia Bayliss-Brown and Nils-Christian Stenseth**
Long-term trends in the biomass of commercial fish in the North Sea: The role of fishing impacts, predator-prey interactions and temperature change (S10-9894)

09:40 **Kelly Ortega-Cisneros and Kevern L. Cochrane**
Modelling impacts of climate change on fisheries in the southern Benguela system (S10-9849)

10:00 **Bryony L. Townhill, Julian D. Metcalfe, David A. Righton and John K. Pinnegar**
Fisheries, low oxygen and climate change: Integrating physiological data with model projections (S10-9828)

10:20 **Anne B. Hollowed , Kerim Aydin, Al Hermann and Kirstin Holsman**
A framework for evaluating IPCC AR5 projected climate change impacts on Bering Sea (AK) fish and fisheries (S10-10250)

10:40 ***Coffee/Tea Break***

11:10 **Alistair J. Hobday, Claire M. Spillman, J. Paige Eveson and Jason R. Hartog**
Seasonal forecasting as a stepping stone to climate adaptation in marine fisheries and aquaculture (S10-9903)

11:30 **Melissa A. Haltuch, Z. Teresa A'mar, Nicholas A. Bond and Juan L. Valero**
Assessing the future effects of climate change trends on U.S. west coast sablefish productivity and on the performance of alternative management strategies (S10-9927)

11:50 **Josephine Dianne Deauna, Olivia Cabrera, Patrick Pata, Cesar L. Villanoy, Roselle Borja, Laura David and Asuncion de Guzman**
Temporal variability of upwelling parameters in the Zamboanga Peninsula, Philippines and its relationship with sardine production (S10-10010)

12:10 **Carey R. McGilliard, André E. Punt, Jim Ianelli and Grant Thompson**
Quantitative tools for predicting fish population dynamics and evaluating alternative harvest strategies under climate change for marine fisheries in Alaska (S10-10221)

12:30 Session ends

Friday, March 27
Plenary

Plenary Session, Day 4

09:00	**Micha J.A. Rijkenberg** Bio-essential and pollutant trace metals in a changing Atlantic Ocean (S3-10023)
09:35	**Philip L. Munday** Predicting evolutionary responses to climate change in the sea: Progress and challenges (S7-10021)
10:10	**Coleen L. Moloney** Going nowhere or moving on: How do changes in species distribution impact marine food webs? (S9-10247)
10:45	***Coffee/Tea Break***
11:15	Sessions 3, 7, 8, 9
15:40	***Coffee/Tea Break***
16:10	General Plenary and Closing Ceremony
17:30	Symposium ends

Friday, March 27

Session 3 S3

Changing ocean chemistry: From trace elements and isotopes to radio-chemistry and organic chemicals of environmental concern

Co-Convenors:
Angelica Peña (Institute of Ocean Sciences, Fisheries and Oceans Canada, Canada)
Geraldine Sarthou (University of Brest, France)

Invited Speaker:
Maeve Lohan (School of Geography, Earth and Environmental Sciences, University of Plymouth, UK)

Ocean chemistry has changed during the Anthropocene. International efforts such as GEOTRACES have improved scientific understanding of the marine biogeochemical cycles and distributions of trace elements, isotopes and organic chemicals in the marine environment, and their synergistic relationships with anthropogenic drivers and climate change. This session invites presentations on assessments and understanding of changes in ocean chemistry including trace elements, isotopes, radiochemistry and organic chemicals of environmental concern. Areas of focus include: (1) historical and future trends in ocean chemistry and synergistic relationships with marine biogeochemistry and ecosystems; (2) scientific outcomes of recent work on the marine biogeochemical cycles of trace elements, isotopes, radiochemistry and organic chemicals, and measurements of change in ocean chemistry (*e.g.*, iron, mercury, lead, organic chemicals, petroleum, and plastics); and (3) future challenges facing the study of changes in ocean chemistry associated with anthropogenic drivers and climate change.

Friday, March 27 (11:15-15:40)

11:15 ***Introduction by Convenors***

11:20 **Maeve C. Lohan, Neil Wyatt, Derek Vance, Susuan H. Little, Ye Zhao, Rob Middag and Hein deBarr (Invited)**
The role of the Southern Ocean export in the biogeochemical cycling of zinc, cadmium and cobalt in the Atlantic Ocean (S3-10030)

11:50 **Leonardo Contreira-Pereira, Carlos F.F. de Andrade, Karina Attisano, Kayla Lima, Mariele Paiva, Gabriel Karagiannis, Cátia Von-Ahn, Daniel Costa and Luis Felipe Hax Niencheski**
Study of the sources of iron to the southern Brazilian coast and adjacent ocean (S3-10204)

12:10 **Sarah L.C. Giering, Sebastian Steigenberger, Eric P. Achterberg, Richard Sanders and Daniel J. Mayor**
Potential changes in iron availability through long-term changes in zooplankton (S3-10065)

12:30 ***Lunch***

14:00 **Géraldine Sarthou, Fabien Quéroué, Fanny Chever, Pier van der Merwe, Delphine Lannuzel, Ashley T. Townsend, Eva Bucciarelli, Hélène F. Planquette, Marie Cheize, Stéphane Blain, Francesco d'Ovidio and Andy R. Bowie**
High variability of dissolved iron concentrations in the vicinity of the Kerguelen Island (Southern Ocean) (S3-10014)

14:20 **Vanessa Hatje, Kenneth W. Bruland and A. Russell Flegal**
Temporal and spatial gradients of anthropogenic Gd in San Francisco Bay (S3-9933)

14:40 **Konstantin Choumiline, Timothy Lyons, Ligia Perez-Cruz and Marisol Escorza-Reyes**
Historical trends in hypoxia of the southeastern Gulf of California: 18,000 year record within Pescadero Basin sediments (S3-10155)

15:00 **Yongwen Gao**
Stable isotopic records of otoliths and clam shells in detecting the climate change and the effects of ocean acidification (S3-9862)

15:20 **Pedro Echeveste, Cristóbal Galbán-Malagón, Jordi Dachs and Susana Agustí**
Interactions of persistent organic pollutants with marine phytoplankton in temperate and polar seawaters (S3-10064)

15:40 Session ends

Friday, March 27

Session 7 S7

Evolutionary response of marine organisms to climate change

Co-Convenor:
Philip Munday (ARC Centre of Excellence for Coral Reef Studies/School of Marine and Tropical Biology, James Cook University, Australia)

Invited Speaker:
Robin Waples (Northwest Fisheries Science Center, USA)

Can organisms keep track with the environmental changes, and what is the evidence? Global change is affecting marine organisms through alterations of both the biotic and abiotic environment. Significant changes have been observed in relation to temperature, oxygen and other biogeochemical properties, but also changes in species composition and interactions are abundant. When organisms face altered environmental conditions they can acclimatize through phenotypic plasticity, migrate to favorable conditions or adapt genetically to the altered selection regime. In recent years, ecological evidence has been accumulating on changes in phenology, behavior and distribution of marine organisms, the latter including model-based forecasting. In contrast, there is a scarcity of genetically based evidence for evolution in response to climate change. This holds for both quantitative and molecular genetic investigations attempting to disentangle environmental and evolutionary effects on the observed trait changes. Insights of the speed and magnitude of evolutionary changes in marine organisms will be of paramount importance for understanding and predicting impacts of climate change in the sea and the associated ecosystem services. For this session we will focus on studies of the effect of climate change on marine organisms with evidence of evolutionary responses. We invite contributions using either molecular genetic or quantitative genetic methods, including long-term temporal genetic studies. Likewise, model-based predictions of species distributions, ecosystem changes and related bio-economical services, which take evolution into account, are encouraged.

Friday, March 27 (11:15-15:20)

11:15 ***Introduction by Convenors***

11:20 **Robin S. Waples and Asta Audzijonyte (Invited)**
Predicting life history changes in marine ecotherms responding to directional climate change and fluctuating productivity regimes (S7-10195)

11:50 **David Abrego and Emily Howells**
Early survival of coral juveniles and initial uptake of algal symbionts in the world's hottest reefs (S7-10121)

12:10 **Andrew Thomas Jones, Shane Lavery, Jennifer Ovenden and You-Gan Wang**
Robust monitoring of genetic effective population size in a changing environment (S7-10006)

12:30 ***Lunch***

14:00 **Emily Howells, David Abrego and John Burt**
Adaptation of coral symbioses to extreme temperatures (S7-9887)

14:20 **Jorge E. Ramos, Gretta Pecl, Natalie A. Moltschaniwskyj, Jayson M. Semmensand Jan M. Strugnell**
Population genetic signatures of a recent marine range extension (S7-9945)

14:40 **Ayako Suda, Yukari Suzuki-Ohno, Mitsuhiko P. Sato, Yoji Narimatsu and Masakado Kawata**
Different responses to water temperature in two distinct groups of Pacific cod (*Gadus macrocephalus*) inhabiting around Japan (S7-10171)

15:00 **Fabiano Thompson, Christine Paillard, Yves-Marie Paulet, Flavia Nunes, Stéphanie Bordenave, Gilberto Amado Fo, Leonardo Tavares, Rodrigo Moura, Paulo Salomon, Giselle Cavalcanti, Arthur Silva and Carlos Rezende**
Effects of global changes in health and disease of carbonatic holobionts (S7-10251)

15:20 Session ends

Friday, March 27

Session 8, Day 3 S8

Climate change impacts on marine biodiversity and resilience

Co-Convenors:
Patricia Miloslavich (Universidad Simon Bolivar, Venezuela)
Jake Rice (Fisheries and Oceans Canada, Canada)

Invited Speaker:
Camilo Mora (University of Hawaii, USA)

Biodiversity is often viewed as an ecosystem characteristic of a healthy environment that enables resilience to perturbations. Climate change can impact community composition resulting in loss of habitat, timing of life cycle events, changes in species distribution that either removes a species from the system or introduces a new species. These impacts affect the function and structure of regional marine ecosystems on various spatial and temporal scales. Climate variability is projected to change the magnitude and frequency of extreme events such that marine ecosystems may be pushed to a tipping point beyond which new processes and structures may emerge. This session encourages papers that investigate observed and predicted impacts of climate change and variability on marine biodiversity and regional ecosystem resilience.

Friday, Day 3, March 27 (11:15-15:20)

11:15 ***Introduction by Convenors***

11:20 **Joana Boavida-Portugal, José R. Paula, François Guilhaumon, Miguel B. Araújo and Rui Rosa**
Global patterns of Tunas and Billfishes (marlins): Present and future (S8-9923)

11:40 **Francisco Barros**
Beta, alpha and gamma benthic diversity on estuaries: What to expect? (S8-9971)

12:00 **Johanna Yletyinen, Örjan Bodin, Benjamin Weigel, Marie C. Nordström, Erik Bonsdorff and Thorsten Blenckner**
Understanding marine regime shifts: Detecting possible changes in structures and functions in coastal and pelagic food webs (S8-9975)

12:20 **Daniel G. Boyce, Kenneth T. Frank, Boris Worm and William C. Leggett**
Macroecological patterns of trophic structure and community stability in marine ecosystems (S8-9978)

12:40 ***Lunch***

14:00 **Cosimo Solidoro, Paolo Lazzari, Gianpiero Cossarini, Giovanni Galli, Donata Melaku Canu, Marcello Vichi, Tomas Lovato, Michele Scardi, Simonetta Fraschetti, Corinne Martin and Marianna Giannoulaki**
Modelling Mediterranean Sea ecosystem state under contemporary and future climate (S8-10061)

14:20 **José R. Paula, Joana Boavida-Portugal, Alexandra S. Grutter, Miguel B. Araújo and Rui Rosa**
Future global patterns of marine cleaning interactions (S8-10067)

14:40 **K. Allison Smith (K.A.S. Mislan), John P. Dunne and Jorge L. Sarmiento**
Diversity of blood-oxygen binding traits in the global ocean (S8-10126)

15:20 Session ends

Friday, March 27

Session S9

Impact of climate change on ecosystem carrying capacity via food-web spatial relocations

Co-Convenor:
Brian R. MacKenzie (Technical University of Denmark, Denmark)

Invited Speaker:
Jason Link (NOAA Fisheries, USA)

Individual species are expected to respond to climate change effects on oceans in regionally-distinct ways according to the limits of their life history traits. One response will be changes in spatial extent with impacts on ecosystem structure through emigrations and immigrations that open or fill new niches. Regional food web linkages are expected to relocate, and trophic interactions become modified by shifts in space and time of the prey, predator, or competitor. This session offers the opportunity to present innovative food-web linkages modeling tools that include expected species spatial re-locations. Contributions can describe past and forecast future changes in global or regional trophic interactions (*e.g.*, predator-prey interactions, competition) due to climate impacts on species biology (*e.g.*, changes in abundances, distributions, vulnerabilities to new abiotic conditions including pH and hypoxia). Papers predicting where interactions might occur under future climate scenarios are encouraged.

Friday, March 27 (11:15-15:40)

11:15 ***Introduction by Convenors***

11:20 **Jason S. Link (Invited)**
Moving parts of the food web: Detecting and predicting climate-induced migratory changes to structure, function, resilience and production of marine ecosystems (S9-9960)

11:50 **Xochitl Cormon, Alexander Kempf, Khalef Rabhi, Manuel Rouquette, Youen VermardMorten Vinther and Paul Marchal**
Evaluation of potential trophic impacts from hake (*Merluccius merluccius*) emergence in the North Sea (S9-10012)

12:10 **Susa Niiranen, James R. Watson and Thorsten Blenckner**
Does body-size matter when marine systems face climate change? (S9-10026)

12:30 ***Lunch***

13:40 **Thorsten Werner, Nelly Tremblay, Kim Hünerlage and Friedrich Buchholz**
Krill worldwide: A comparison of hypoxia tolerances of euphausiid species from Atlantic, Pacific and Polar regions (S9-10182)

14:00 **Philipp Brun, Thomas Kiørboe Priscilla Licandroand Mark R. Payne**
The predictive potential of ecological niche models for plankton in the North Atlantic (S9-9839)

14:20 **Myron A. Peck, Marc Hufnagl, Klaus Huebert and Markus Kreus**
Advancing tools to examine climate-driven changes in trophic coupling: Physiological-based modelling of early life stages of North Sea fishes (S9-10259)

14:40 **Tore Johannessen**
Empirical evidence suggests that global warming may induce abrupt shifts in plankton communities and subsequent recruitment failure in fishes (S9-10249)

15:00 **Hjálmar Hátún, Katja Lohmann, Daniela Matei, Johan Jungclaus, Selma Pacariz, Sólveig. R. Ólafsdóttir, Jón Ólafsson and Manfred Bersch**
Labrador Sea convection blows life to the northeastern Atlantic (S9-9906)

15:20 **Brian R. MacKenzie, Mark R. Payne, Jesper Boje, Jacob L. Høyer and Helle Siegstad**
A cascade of warming impacts brings bluefin tuna to Greenland waters (S9-9891)

15:40 Session ends

List of Posters

S1 Posters
Role of advection and mixing in ocean biogeochemistry and marine ecosystems

S1-P1 Rosabruna **La Ferla**, Maurizio Azzaro, Gabriella Caruso, Renata Zaccone, Giovanna Maimone, Franco Decembrini, Rodolfo Paranhos, Anderson S. Cabral, Marco Pansera and Giuseppe Civitarese
Microbial biogeochemistry in the Southern European Seas: The multidisciplinary ADREX survey

S1-P2 Xingrong **Chen** and Yi Cai
The use of physical decomposition to analyze interannual climate variability in the southern Indian Ocean

S1-P3 Anahí A. **Brun**, Marcelo Acha and Alberto R. Piola
Transoceanic fluxes in southern Patagonia

S1-P4 Ramiro **Riquelme-Bugueño**, Jocelyn Silva-Aburto, Celia Ballotta, Silvio Pantoja, Rubén Escribano, Wolfgang Schneider and Pamela Hidalgo
Growth rate and fatty acid composition in the Humboldt Current krill, *Euphausia mucronata*, in the coastal upwelling zone off central Chile

S1-P5 Karina Kammer **Attisano**, Isaac Rodrigues Santos, Carlos F.F. de Andrade, Mariele Lopes de Paiva, Idel Cristina Bigliardi Milani and Luis Felipe Hax Niencheski
Submarine Groundwater Discharge for the coastal region in southern Brazil

S1-P6 Carlos A. **Cantergiani**, Carol C. González, Guillermo Feliú and Pamela Hidalgo
Vertical migrations of copepods in the oxygen minimum zone: Conceptual model approach and it simplication of the bioelement fluxes

S1-P7 Carol C. **González**, Carlos A. Cantergiani, Guillermo Feliú and Pamela Hidalgo
Abundance and biomass of live and dead copepods associated with the oxygen minimum zone in northern Chile (23°S)

S1-P8 Jianfang **Chen**, Martin G. Wiesner, Hongliang Li, Lihua Ran, Niko Lahajnar and Ronghua Chen
The effect of advection on biogenic fluxes and paleo-proxies in the deep South China Sea

S1-P9 Nancy K. **Taniguchi**, Silvia H.M. Sousa, Cristiano M. Chiessi, Henning Kuhnert, Rubens C.L. Figueira and Stefan Mulitza
Implications of North Brazil Current variations during the last 8000 cal years BP and its role in the paleoclimate on Northeast Brazilian margin

S1-P10 Kayla Lima, Luiza Dy F. Costa, Mônica **Wallner-Kersanach**, Carlos F.F. de Andrade, Karina Attisano, Camila Sukekava, Leonardo Contreira, Mariele Paiva, Iarema Ferreira Pinto de Carvalho and Luis Felipe Hax Niencheski
Nutrient concentrations along the coast of southern Brazil

S1-P11 Selma **Pacariz**, Hjálmar Hátún, Jan Arge Jacobsen, Anna Ólafsdottir and Inga Kristiansen
Nutrient limitation in the subpolar North Atlantic drives mackerel westwards

S2 Posters
Ocean acidification

S2-P1 Mary Chris **Lagumen** and Maria Lourdes San Diego-McGlone
Assessment of acidification and eutrophication in the coastal waters of Bolinao, Pangasinan, Philippines

S2-P2 José A. **Fernandes**, Eleni Papathanasopoulou, Ana M. Queirós, William W.L. Cheung, Andrew Yool, Yuri Artioli, Nicola Beaumont, Stephen Widdicombe, Melanie Austen, Manuel Barange and Caroline Hattam
End-to-end assessment of ocean warming and acidification on fisheries: From experiments and models to economic and social impacts

S2-P3 Kannan **Gunasekaran**, Deivasegamani Selvam, Renganathan Mahesh and Ayyappan Saravanakumar
Impact of ocean acidification on marine clownfish sperm behaviour and fertilization of *Amphiprion sebae*

S2-P4 Adriana R. **Perretti**, Cristiano M. Chiessi, Cintia Yamashita and Silvia H.M. Sousa
A 12 ka history about changes in deep ocean carbonate chemistry and its effects on foraminiferal tests

S2-P5 Rosa **Freitas**, Adília Pires, Anthony Moreira, Ângela Almeida, Cátia Velez, Amadeu M.V.M. Soares and Etelvina Figueira
Effects of seawater acidification on *Diopatra neapolitana* (Polychaete, Onuphidae) performance: Biochemical and regenerative capacity responses

S2-P6 Rosa **Freitas**, Ângela Almeida, Vânia Calisto, Cátia Velez, Anthony Moreira, Rudolf Schneider, Valdemar Esteves, Amadeu M.V.M. Soares and Etelvina Figueira
How life history influences the responses of the clam *Scrobicularia plana* to the combined impacts of pH decrease and carbamazepine

S2-P7 Etelvina **Figueira**, Cátia Velez, Vanessa Carregosa, Joana Pinto, Sara Pereira, Ana Gil, Amadeu M.V.M. Soares and Rosa Freitas
Biochemical and metabolomic alterations in the invasive clam *Venerupis philippinarum* when exposed to salinity changes

S2-P8 Dominika **Brulińska**, Adam Sokołowski and Zuzanna Mirny
Effect of elevated carbon dioxide concentrations on the growth of estuarine bivalve *Macoma balthica* from the Baltic Sea

S2-P9 Laura **Sordo**, Rui Santos, Isabel Barrote and João Silva
Long-term effects of ocean acidification on free-living coralline algae

S2-P10 Visnu C. **Sarmento**, Tarciane P. Souza, André M. Esteves and Paulo J.P. Santos
Effects of seawater acidification on a coral reef meiofauna community

S2-P11 Rui **Zhang**
Response of bacterioplankton interaction to acidification in the Arctic Ocean revealed by phylogenic molecular ecological networks

S2-P12 Marta S. **Pimentel**, Filipa Faleiro, Gisela Dionísio, Jorge Machado, Mário S. Diniz, Pedro Pousão-Ferreira, José R. Paula, Myron A. Peck, Hans Pörtner, Rui Rosa
Sparus aurata and *Argyrosomus regius* early life stages responses to ocean warming and acidification

S2-P13 Jean-Philippe Savy, Olivier Marcou, Alan Poisson, Nathalie Poisson, Franck Touratier, Catherine Goyet and Jannine M.L. **Avila**
Variations of AT, CT and pH in Indian Austral Ocean between 2005 and 2010 in response to cooling and evaporation

S2-P14 Tarciane P. **Souza**, Visnu C. Sarmento, André M. Esteves and Paulo J.P. Santos
Effects of seawater acidification on a coral reef Nematoda community

S2-P15 Geniane Schneider, Paulo Horta, Camilla Reis, Isabel Brandalise, José Bonomi Barufi and Ana Claudia **Rodrigues**
Effect of ocean acidification in the ecophysiology and ultrastructure of *Halodule wrightii* Ascherson – An evaluation in a tropical mesocom

S2-P16 Mônica **Wallner-Kersanach**, Luis Felipe Hax Niencheski,Carlos F.F. de Andrade, Karina Attisano, Kayla Lima, Camila Sukekava, Leonardo Contreira, Daniel Costa, Joselene de Oliveira, Eunice Machado, Alice Costa, Rodrigo Kerr, Luiza Dy F. Costa and Iarema F.P. de Carvalho
The submarine groundwater process, the biological pump and the CO_2 fluxes on the Brazilian southeastern and southern shelf

S2-P17 Aniko **Zseni** and Eva V. Pestine **Racz**
Acidification of Europe's seas: An overview based on the European Climate Adaptation Database

S3 Posters
Changing ocean chemistry: From trace elements and isotopes to radiochemistry and organic chemicals of environmental concern

S3-P1 Silvia K. **Kawakami**, Heyde Gomes, Camila Evangelista, Leonardo Melo and Rafael Aquino
Natural and anthropogenic sedimentary organic compounds in the Guajará Bay, an urbanized Amazonian coastal system (Pará, North Brazil)

S3-P2 Jasmin G. **John**, John P. Dunne and Charles A. Stock
Fingerprints of centennial climate change on ocean biogeochemistry

S3-P3 Natalia **Ospina-Alvarez**, Ricardo Prego and Manuel Varela
Land-sea boundary as a reference for analysis of environmental changes: Sinking particle fluxes of metals and organic matter in a mesotrophic pristine coastal system

S3-P4 Lucia H. **Vieira**, Eric P. Achterberg, Michiel M. Rutgers van der Loeff, Jan Scholten and Joaquin Pampin Baro
Ra isotopes as tracers of iron (Fe) sources supplying the phytoplankton blooms under the ice in the Arctic Ocean

S3-P5 Kirsten **Isensee**, Laura Lorenzoni, Todd O'Brien and Luis Valdés
IGMETS: Assessing global oceanic changes one time-series at a time

S3-P6 Julianna Ma. de A. **Martins**, Renato da Silva Carreira, Elizabeth A. Canuel and Erin Ferer
Guanabara Bay organic matter flux and its influence in the adjacent continental shelf

S3-P7 Etelvina **Figueira**, Cátia Velez, Luís Salamanca, Paulo Cardoso, Silvia Rocha, Amadeu M.V.M. Soares and Rosa Freitas
Biochemical and metabolomic alterations in the invasive clam *Venerupis philippinarum* when exposed to salinity changes and Arsenic contamination

S4 Posters
Regional models for predictions of climate change impacts: Methods, uncertainties and challenges

S4-P1 Ana M. **Queirós**, José A. Fernandes, Sarah Faulwetter, Joana Nunes, Samuel P.S. Rastrick, Nova Mieszkowska, Yuri Artioli, Andrew Yool, Piero Calosi, Christos Arvanitidis, Helen S. Findlay, Manuel Barange, William W.L. Cheung and Stephen Widdicombe
Scaling up experimental ocean acidification and warming research: From individuals to the ecosystem

S4-P2 Edson J.P. **Pereira** and Ilana Wainer
Ocean climate projections downscaled for the Arabian Gulf

S4-P3 José A. **Fernandes**, Simon Jennings, Stephen D. Simpson, Louise A. Rutterford, William W.L. Cheung, Manuel Barange and Alastair Grant
Multivariate comparison of modelled and realised changes in fish abundance and distribution in response to climate

S4-P4 Yang Liu, Sei-Ichi **Saitoh** and Toru Hirawake
The impacts of climate change on marine environment variation to Japanese scallop growth in Funka Bay, Japan using MODIS and OGCM

S4-P5 Jinkun **Yang** and Yulong Liu
Mode analysis of Indian-Pacific Sea surface temperature anomaly

S5 Posters
Coastal blue carbon and other ocean carbon sinks

S5-P1 Lucía C. **Kahl**, Alejandro A. Bianchi, Ana Paula Osiroff, Diana Ruiz Pino and Alberto R. Piola
Space variability of sea-air CO_2 fluxes in the Patagonian Sea: Seasonal biological and thermal effects on CO_2

S5-P2 Tiziana Luisetti, Kerry R. Turner, Martin Johnson, Tim Jickells, Julian Andrews, Maria G. Palmieri, Lucille Paltriguera, Silke Kroeger, Keith Weston, Silvana **Birchenough**, Dorothee Bakker, Claire Powell and Ruth Parker
The shelf-life of blue carbon

S5-P3 Silvana **Birchenough**, Susana Lincoln, Keith Weston and Silke Kroeger
Blue carbon exchanges and storage: Assessing the role of human activities and management implications

S5-P4 Jannine M.L. **Avila**, Rosane G. Ito and Carlos E.A. Garcia
Sea-air carbon dioxide fluxes along 35°S in the South Atlantic Ocean and adjacent continental shelves

S6 Posters
Climate change in the seasonal domain: Impacts on the phenology of marine ecosystems and their consequences

S6-P1 Hongjun **Song**, Mingzhu Fu, Xinming Pu and Xuelei Zhang
Plankton biogeography and phenology in the Southern Yellow Sea

S6-P2 Ismael **Núñez-Riboni** and Anna Akimova
Causes and effects of hydrography changes in the North Sea from the inter-annual to multi-decadal time scales

S6-P3 Felipe **Gusmão** and Rubens M. Lopes
Long term zooplankton variability in a South Atlantic coastal channel and its relationship with climatic indices

S6-P4 Yun **Li**, Rubao Ji, Paula S. Fratantoni, Changsheng Chen, Yunfang Sun and Jonathan A. Hare
Changing rhythm of stratification on the Northwest Atlantic shelf: Interannual variability and its biological implications

S6-P5 Christopher A. **Griffiths**, Beth Scott and Julia L. Blanchard
Juvenile sandeel growth: An individual's physiological and phenological response to climatic warming

S6-P6 Carlos A. **Cantergiani**, Carol C. González, Guillermo Feliú and Pamela Hidalgo
Annual variability in the composition and abundance of the zooplanktonic communities associated with the upwelling zone in Mejillones Bay (23°S), northern Chile

S6-P7 José E. Martinelli **Filho** and Rubens M. Lopes
Cyclopoid copepods in a subtropical coastal area (Ubatuba, Brazil): Growth rates and production

S6-P8 Arno **Põllumäe**, Liina Pajusalu and Georg Martin
Macrophyte community response to the changing water temperature in a shallow brackish water Kõiguste Bay

S6-P0 Alexandra **Temnykh** and Mikhail Silakov
Seasonal cycles of mesoplankton in different climatic periods in the open coastal waters near Crimea (Black Sea)

S7 Posters
Evolutionary response of marine organisms to climate change

S7-P1 Claire Samantha T. **Juanico**, Shiao-Wei Huang and Hon-Tsen Yu
Changes in conservation units of some tiger shrimp populations in Southeast Asia

S7-P2 Marcela **Cornejo**, Pamela Hidalgo, Paula Ruz and Ramiro Riquelme-Bugueño
Effects of hypoxia on nitrogen fluxes of *Acartiatonsa* in the oxygen minimum zone of the eastern south Pacific

S8 Posters
Climate change impacts on marine biodiversity and resilience

S8-P1 Pavan **Kumar**, Meenu Rani and Vandana Tomar
Identification of coral reef bleaching warming in Gulf of Kachchh using climatology parameter by geospatial techniques

S8-P2 Inês **Leal**, Vanessa Mendonça, Diana Madeira, Luís Narciso, Mário S. Diniz, Augusto A.V. Flores and Catarina Vinagre
Vulnerability of tropical and temperate coastal organisms to climate change

S8-P3 Catarina **Vinagre**, Maria J. Costa, Spencer A. Wood, Richard J. Williams and Jennifer A. Dunne
Network structure of estuarine food webs – The role of humans and climate change

S8-P4 Laura J. **Falkenberg** and Craig A. Styan
A novel method to identify the effects of climate change: Potential insights for future biodiversity and ecosystem resilience

S8-P5 Elvira **Poloczanska**, Anthony J. Richardson and Alistair J. Hobday
Marine climate change impacts and adaptation report card for Australia

S8-P6 Alagarsamy **Sakthivel**, Periyasamy Selvakumar and Ayyaru Gopalakrishnan
Histological and scanning electron microscopic studies on internal parasite *Echinorhynchus* sp in yellowfin tuna (*Thunnus albacares*)

S8-P7 Matthew B. **Sanders**, Kelly S. Bateman, Craig Stenton, Rose C. Kerr and Grant D. Stentiford
Effect of ocean acidification on white spot syndrome virus (WSSV) replication in juvenile European lobster (*Homarus gammarus*)

S8-P8 Makamas **Sutthacheep**, Thamasak Yeemin, Kazuhiko Sakai, Sittiporn Pengsakun, Wanlaya Klinthong and Charernmee Chamchoy
Coral reef resilience to climate change in the Gulf of Thailand and the Andaman Sea

S8-P9 W.A.S. **Chamika**, M.B.M. Fayas, G.G.E.M. Gunasekara, I.M.I.S.B. Gunathilake, I.P.S. Chandrasiri and M.F.M. Fairoz
Current status of microbial activity at Pareviwella reef Tangalle southern Sri Lanka

S8-P10 Eva **Cacabelos**, Gustavo M. Martins, Richard Thompson, Afonso Prestes, José Manuel N. Azevedo and Ana I. Neto
Marine assemblages on natural shores and coastal defence structures

S8-P11 Visnu C. **Sarmento**, Tarciane P. Souza, Djamilla S. Andrade, Ítalo S. Azevedo, André M. Esteves and Paulo J.P. Santos
Effects of climate change scenarios on a coral reef meiofauna community

S8-P12 Rodolfo F.M. **Nascimento**, Visnu C. Sarmentoand Paulo J.P. Santos
Response of *Halimeda* sp. to a climate change scenario

S8-P13 Jesús S. **Troncoso**, Marcos Rubal, Puri Veiga, Juan Moreira and Isabel Sousa-Pinto
Enlargement and reductions on habitat of sub-tropical and boreal intertidal species of gastropods along Atlantic coast of Iberian Peninsula in a global warming scenario

S8-P14 Zelinda M.A.N. Leão, Ruy Kenji P. **Kikuchi** and Marília D.M. Oliveira
Coral bleaching in Brazil

S8-P15 Meri Bilan, Gisela **Dionísio**, Ricardo Calado and Rui Rosa
Ontogenic development of tropical photosynthetic mollusks in a changing ocean

S8-P16 Helena **Matthews-Cascon**, Hilton de Castro Galvão Filho and Carlos Augusto Oliveira de Meirelles
Population density of *Bursatella leachii* (Mollusca: Gastropoda) in three estuaries of Ceará State, Northeast Brazil

S8-P17 Carlos Augusto Oliveira de **Meirelles**, Maurizélia de Brito Silva and Helena Matthews-Cascon
Aplysia dactylomela (Mollusca: Gastropoda) from Rocas Atoll (RN – Brazil): Where did it go?

S8-P18 D. Sanna **Durgappa** and Nitish Venkateshwaralu
Impact of climate change on marine biodiversity in west coast of India

S8-P19 Marina S. Barroso, Visnu C. **Sarmento** and Paulo J.P. Santos
Effects of increasing seawater temperature on phytal meiofauna community

S8-P20 Sofia Francisco, Marta S. Pimentel, José R. **Paula**, Inês Rosa, Vanessa Madeira, Tiago Repolho, António Marques and Rui Rosa
Combined effects of climate change and methylmercury exposure on marine fish ecophysiology

S8-P21 Juan I. **Cañete**, Carlos S. Gallardo, Javier Díaz-Ochoa, María S. Romero, Carlos Olave and Tania Figueroa
Estuarine neustonic communities: Oceanographic tool to relate climate change with fluctuation in salinity at southern Chilean fjords

S8-P22 Juan I. **Cañete**, Xavier Turon, Rosana M. Rocha and Javier Sellanes
Distribution patterns of native and exotic ascidians in two areas of Chile with contrasting oceanographic features and human activity record

S8-P23 Ítalo **Lima** and Marcelo Soares
Coral bleaching in a highly turbid environment: A reef monitoring through 2 years in an equatorial coast (NE, Brazil)

S8-P24 Tore **Johannessen**
Predator-prey synergism – A novel perspective in ecology

S8-P25 Ian **McCarthy**, Hana Cox, Mallory Diggens, Yeny Kamaruzzaman, Clara MacKenzie, Ruth Nicholls, Coleen Suckling, Ben Ciotti, Luis Gimenez, Shelagh Malham, Chris Hauton and Nia Whiteley
Assessing impacts of ocean acidification on energy status of marine invertebrates

S8-P26 Coleen Suckling, Luis Gimenez, Ian **McCarthy**, Ben Ciotti, James Brown, Chris Hauton and Nia Whiteley
Metabolic responses of two species of brachyuran crustaceans to ocean acidification and reduced salinity

S9 Posters
Impact of climate change on ecosystem carrying capacity via food-web spatial relocations

S9-P1 Wilhelm **Hagen**, Anna Schukat and Holger Auel
Life strategies and dietary interactions of copepods in the northern Benguela upwelling system

S9-P2 Holger **Auel**, Maya Bode, Flavia Höring, Lena Teuber, Wilhelm Hagen and Anna Schukat
Impact of hypoxia on zooplankton communities in the subtropical and tropical Atlantic Ocean

S9-P3 Katherine E. **Mills**, Andrew J. Pershing, Christina Hernandez, Janet Nye and Lis Henderson
Integrating species distribution, phenology, body size, and abundance to evaluate climate impacts on marine trophic interactions

S9-P4 Julie E. **Keister**, Tim E. Essington, Mei Sato, John K. Horne, Sandra L. Parker-Stetter and Amanda K. Winans
Consequences of hypoxia on distributions, species composition, predator-prey interactions, and energy flow in a pelagic marine ecosystem

S10 Posters
Forecasting climate change impacts on fish populations and fisheries

S10-P1 Nick **Caputi**, Simon de Lestang, Ming Feng, Ainslie Denham, James Penn, Dirk Slawinski, Alan Pearce and Jason How
Decline in puerulus settlement in the western rock lobster fishery in Western Australia: A climate change effect?

S10-P2 Diana **Perry**, Thomas Staveley and Martin Gullström
Marine shallow water seascapes under a changing climate: A seagrass perspective

S10-P3 Alexander **Zavolokin** and Lidia Zavarina
Long-term trends in growth of Kamchatka chum salmon (*Oncorhynchus keta*) in relationship to climate and salmon abundance, 1927-2012

S10-P4 Shin-ichi **Ito**, Takeshi Okunishi, Michio J. Kishi and Muyin Wang
Modelling ecological responses of Pacific saury (*Cololabis saira*) to future climate change and its uncertainty

S10-P5 Hwa Hyun **Lee**, Sukyung Kang, Kyungmi Jung, Suam Kim andSukgeun Jung
Buoyancy and vertical distribution of Pacific Mackerel eggs and larvae and its climate change implication for the temporal variability of recruitment

S10-P6 Walter H.D. **Pinaya** and Ronald B. Souza
The Brazilian sardine (*Sardinella brasiliensis*) landings and its relationship with the marine variability in the Southeast Brazilian Bight (SBB)

S10-P7 Andrew J. **Pershing**, Katherine E. Mills, Andrew Thomas, Nicholas R. Record and Christina Hernandez
Impact of rapid warming on the Gulf of Maine ecosystem

S12 Poster
Linking climate change to marine management objectives

S12-P1 Keshnee **Pillay**
South African ocean monitoring: A new era

General Posters

GP-P1 Michael Adedotun **Oke**
Overview and experiences gathering during boat tour in ocean of Ghana

GP-P2 Frédéric Kpèdonou **Bonou**, Moacyr Araújo and Nathalie Lefèvre
Variability of total alkalinity and total inorganic carbon in the western tropical Atlantic Ocean

GP-P3 Sara **Bojórquez-Sánchez**, Ana Carolina Ruiz-Fernández, Ana Judith Marmolejo-Rodríguez, Alberto Sánchez-González, Joan-Albert Sánchez-Cabeza, Ángel Humberto Ruvalcaba-Díaz, Humberto Bojórquez-Leyva and Libia Hascibe Pérez-Bernal
Recent accretion rates in coastal seasonal floodplain, as an evidence of Global Change in Veracruz, Mexico

GP-P4 Thulwaneng B. **Mashifane**, Howard A. Waldron, Marcello Vichi and Eric Machu
Biogeochemical feedback processes in the oxygen minimum zone of the Benguela upwelling system

GP-P5 Aurore **Regaudie-de-Gioux**, Susana Agustí and C.M. Duarte
UV sensitivity of planktonic net community production in ocean surface waters

GP-P6 Lourianne M. **Freitas**, Ruy Kenji P. Kikuchi, Marília D.M. Oliveira and Zelinda M.A.N. Leão
Calcification response of the coral *Montastraea cavernosa* (Linnaeus, 1767) to heterotrophy during a bleaching event

GP-P7 Raisa de Siqueira **Alves**, Angela Hibbertand Harry Leach
Modes of sea level variability in the South Atlantic

GP-P8 Qingsheng **Miao**, Jinkun Yang, Yang Yang and Ting Yu
Climate response and spatial-temporal model on the inter-annual change of winter temperature-salinity in the East China Sea

GP-P9 Maria Eduarda F. **Mansur**, Tiago C.A. Oliveira, Daniel Rigoand Jacqueline Albino
Implications to erosion in coastal protected areas

GP-P10 Anna **Schukat**, Thorsten Werner, Holger Auel and Wilhelm Hagen
Downward export of carbon by diel migrant zooplankton in the northern Benguela upwelling system with regard to the OMZ

GP-P11 Alexey **Maximov**
Climate-driven changes in disturbed marine ecosystem: The case of the Neva Estuary

GP-P12 Kevern L. **Cochrane**, Mary Gasalla, Alistair J. Hobday, A. Paytan, Ekaterina Popova, H. Razafindrainibe, Shyam S. Salim, C. Savage and W. Sauerand the GULLS team
Global learning for local solutions: Reducing vulnerability of marine-dependent coastal communities

GP-P13 Jennifer C.A. **Pistevos**, Ivan Nagelkerken, Tullio Rossi, Maxime Olmos and Sean D. Connell
Ocean acidification and global warming impair behaviour and growth in an apex predator

GP-P14 Patricia G. **Cardoso**, Gisela Dionísio, Maria Aurélio, José R. Paula, Tiago Grilo and Rui Rosa
How trophic interactions (*Littorina obtusata/Ascophyllum nodosum*) may be endangered by climate change

GP-P15 Lisa **Pfeiffer** and Trevor Gratz
A safer catch? The effects of catch share management on fishing safety

GP-P16 Miryam **Juárez**, Antoni Rosell-Mele, Alberto Sánchezand Oscar Gonzalez-Yajimovich
Paleoproductivity in the northeast Pacific for the last millennium

GP-P17 Rui **Rosa**, Ana Rita Lopes, Inês Rosa, Filipa Faleiro, José R. Paula and Tiago Repolho
Are intertidal shrimps more vulnerable to global warming than subtidal ones?

GP-P18 Iole B.M. **Orselli**, Gastón Alurralde, Flavia Delcourt, Leonardo K. Miyashita and Daniel Valla
A potential tool for detecting Harmful Algal Blooms through remote sensing data

GP-P19 Carmen **Rodriguez**, Fen Huang and Frank Millero
Estimating the effect of pressure on the TRIS buffer system for in-situ pH measurements

GP-P20 Adoté Blim **Blivi**
Predictions of retreat of coastline up to 2025, 2050, 2075, 2100, depletion of sand and effect of sea level rise along gulf of Benin in Eastern Atlantic Ocean

GP-P0 Alexandra **Temnykh** and Mikhail Silakov
Synergetic effect of climate change, anthropogenic eutrophication and invaders on plankton community of the Black Sea

W2/W6 Posters
Joint Brazilian Ocean Acidification Research and Surface Ocean-Lower Atmosphere Study (SOLAS) Workshop: Biogeochemical-physical interactions and feedbacks between the ocean and atmosphere

W2/W6-P1 Marina T. **Botana** and Marius N. Müller
Response of Brazilian phytoplankton to temperature and ocean acidification

W2/W6-P2 Camila Ortulan **Pereira**, Mauricio Shimabukuro, Arthur Ziggiatti Güth and Paulo Yukio Gomes Sumida
Carbon flows through a coastal benthic community under ocean acidification conditions

W2/W6-P3 Iole B.M. **Orselli**, Rodrigo Kerrand Rosane G. Ito
An estimate of anthropogenic CO_2 distribution in Southwestern Atlantic

W3 Posters
Effects of climate change on the biologically-driven ocean carbon pumps

W3-Group 1

W3-G1-P1 Renata Zaccone, Gabriella Caruso, Maurizio Azzaro, Marcella Leonardi, Giovanna Maimone, Luis Monticelli and Rosabruna **La Ferla**
Seasonal and inter-annual changes of microbial activities in the Mediterranean Sea

W3-G1-P2 Louis **Legendre**, Richard B. Rivkin, Markus Weinbauer, Lionel Guidi and Julia Uitz
The microbial carbon pump: Potential significance in the globally changing ocean

W3-G1-P3 DanLing **Tang**, Louis Legendre, QingYang Sun and JinRou Lin
Typhoons impacts on sea-air exchanges of CO_2 and DO in the South China Sea

W3-G1-P4 Lionel **Guidi**, Louis Legendre, Gabriel Reygondeau, Lars Stemmann, Julia Uitz and Stephanie A. Henson
A new look at ocean carbon remineralization for estimating deep-water sequestration

W3-G1-P5 Cynthia H. **Pilskaln**, Kazuhiro Hayashi, Zhaohui Wang, Joe E. Salisbury and Douglas Vandemark
Carbon pump dynamics and budget for the Northwestern Atlantic shelf

W3-G1-P6 Richard B. **Rivkin**
Manna from heaven… Role of aeolian nutrient inputs on carbon pumps in the contemporary and future ocean

W3-G1-P7 Maurizio Azzaro and Rosabruna **La Ferla**
Variability of carbon dioxide production rates in the water masses of Southern Adriatic Pit in the period 1993-2004

W3-G1-P8 Jianfang **Chen**, Martin G. Wiesner, Hongliang Li, Lihua Ran, Niko Lahajnar and Ronghua Chen
Variability of biological pump in the deep northern South China Sea

W3-G1-P9 Nianzhi **Jiao**, Yao Zhang, Farooq Azam and Louis Legendre
Emerging needs for standard protocols for core measurements of the marine carbon sinks

W3-G1-P10 Daniel J. **Mayor**, Richard Sanders, Sarah L.C. Giering and Thomas R. Anderson
Microbial gardening in the ocean's twilight zone: Detritivorous metazoans benefit from fragmenting, rather than ingesting, sinking detritus

W3-Group 2

W3-G2-P11 Xavier **Mari**, Markus G. Weinbauer and Louis Legendre
On the impact of soot deposition on carbon pumps

W3-G2-P12 Markus G. **Weinbauer**
Role of viral lysis of plankton for the cycling of organic matter

W3-G2-P13 Maurizio Azzaro, Leonardo Langone, Giovanna Maimone and Rosabruna **La Ferla**
Carbon dioxide production rates in the Ross Sea (Antarctica)

W3-G2-P14 Maurizio Azzaro, Rosabruna **La Ferla**, Giovanna Maimone, Franco Decembrini, Filippo Azzaro, Carmela Caroppo, Stefano Miserocchi, Federico Giglio, Leonardo Langone, Stefano Aliani, Anderson S. Cabral and Rodolfo Paranhos
Variability of microbial respiratory activity in relation to particulate organic matter over short time scales in a glacial Arctic fjord (Kongsfjorden, Svalbard)

W3-G2-P15 Rui **Zhang**
Viral control on bacterioplankton and its ecological and biogeochemical implicates in the deep western Pacific Ocean

W3-G2-P16 Feng-Ping **Wang**
Roles of archaea in organic matter degradation in marine sediments

W3-G2-P17 Chuanlun **Zhang**, Haodong Liu, Songze Chen, Chunyan Yang, Wei Xie and Peng Wang
Variability in abundance of the Bacterial and Archaeal 16S rRNA and *amoA* genes in water columns of northern South China Sea

W3-G2-P18 Nianzhi **Jiao**, Farooq Azam and Louis Legendre
Marine Ecosystem Experimental Chamber System (MECS) – A powerful tool for scenario studies on climate and environmental changes

W3-G2-P19 Jun **Sun**
Phytoplankton biovolume conversion carbon biomass calculation and its implication for biological pump

W3-Group 3

W3-G3-P20 Stephanie A. **Henson**, Andrew Yool and Richard Sanders
Variability in efficiency of particulate organic carbon export: A model study

W3-G3-P21 Uta **Passow**
Effects of rising atmospheric carbon dioxide concentrations on the biological carbon pump

W3-G3-P22 Jerry **Tjiputra** and Jorg Schwinger
Sensitivity and regional change of future biological carbon pump to POC flux parameterization

W3-G3-P23 Gianpiero **Cossarini**, Stefano Querin and Cosimo Solidoro
The continental shelf pump in the Adriatic Sea (Mediterranean Sea): Modeling the interaction between physical processes and the biogeochemical carbon cycle

W3-G3-P24 Adrian **Burd**
The impact of climate change on aggregation and particle flux in the marine environment

W3-G3-P25 Sarah L.C. **Giering**, Richard Sanders, Richard S. Lampitt, Thomas R. Anderson, Christian Tamburini, Mehdi Boutrif, Mikhail V. Zubkov, Chris M. Marsay, Stephanie A. Henson, Kathryn B. Cook and Daniel J. Mayor
Balancing the carbon budget in the twilight zone

W3-G3-P26 Charlotte **Laufkoetter**, Meike Vogt and Nicolas Gruber
Drivers of future changes in export efficiency in marine ecosystem models

W3-G3-P27 K. Allison **Smith** (K.A.S. Mislan), Charles A. Stock, John P. Dunne and Jorge L. Sarmiento
Particle attenuation simulated using a microbial remineralization model

W3-G3-P28 Fei **Chai** and Peng Xiu
Modeling carbon cycle in the Pacific Ocean

W3-G3-P29 Ya-Wei **Luo** and Nianzhi Jiao
Comparison of microbial carbon pump (MCP) in several open ocean stations using an ecosystem model

W3-G3-P30 M. Robin **Anderson** and Richard B. Rivkin
Cumulative effects of climate change and other anthropogenic pressures on ocean carbon pumps

W5 Posters
Moving towards climate-ready fishery systems: Regional comparisons of climate adaptation in marine fisheries

W5-P1	Emily Ogier, Stewart Frusher, Alistair J. Hobday, Sarah Jennings, Andrew Sullivan and Gretta **Pecl** Evaluating adaption options for four key fisheries in South Eastern Australia
W5-P2	Katherine E. **Mills** and Andrew J. Pershing Following the fish? Fishery responses to shifting fish distributions in the Northeast United States
W5-P3	Andrew J. **Pershing**, Katherine E. Mills, Christina Hernandez, Lisa Kerr and Graham Sherwood Slow management during rapid ecosystem change: How rapid warming drove the collapse of Gulf of Maine cod
W5-P4	Alan **Haynie** and Lisa Pfeiffer Climate change and adaptive fisher behavior in the Pacific cod longline fishery
W5-P5/ S10-P1	Nick **Caputi**, Simon de Lestang, Ming Feng, Ainslie Denham, James Penn, Dirk Slawinski, Alan Pearce and Jason How Decline in puerulus settlement in the western rock lobster fishery in Western Australia: A climate change effect?

Abstracts
Oral Presentations

Keynote

March 23 09:15

Climate Change: Mapping the problem space and the opportunity space

Chris **Field**

Director, Department of Global Ecology, Carnegie Institution for Science
Co-Chair, Working Group II, Intergovernmental Panel on Climate Change

The IPCC Fifth Assessment Report, released in 2013 and 2014 presents a comprehensive picture of the nature of the climate-change challenge and the options for addressing it. In exploring the landscape of observations and projections, the report characterizes physical, biological, and human dimensions, highlighting aspects where multiple interacting mechanisms and persistent uncertainties create risks. These risks emerge not from climate acting in isolation but from the intersection of hazards from climate triggers, vulnerability, and exposure. A wide range of risks have already materialized. Climate changes and impacts of climate changes that have already occurred are evident on all continents and across the oceans.

Future changes and their impacts will depend on future emissions of greenhouse gases, as well as on investments in adaptation. Strong evidence for a relationship between warming and cumulative emissions means that greenhouse gas emissions eventually need to go to zero, independent of the temperature goal. But the risk of impacts and the constraints to addressing them through adaptation increases strongly with the amount of warming. A world of continued high emissions leads to risk of impacts that are severe, pervasive, and in some cases irreversible.

Currently, the world has the opportunity to avoid the word impacts of climate change and stabilize warming in the range of 2°C above pre-industrial levels, but reaching an ambitious goal becomes increasingly difficult with delay, incomplete participation, or limitations on the range of available non-emitting energy technologies. Ambitious action to address climate change, through both adaptation and mitigation, has the potential for a wide range of co-benefits that can enhance sustainable development, contributing to robust economies and vibrant communities.

Plenary Session Presentations

March 23

March 23, 10:45 (S4-10009)

The potential of nested ocean modeling

Arne **Biastoch**

GEOMAR Helmholtz Centre for Ocean Research, Kiel, Germany. E-mail: abiastoch@geomar.de

The choice between resolution and spatial coverage is one of the oldest challenges in ocean modeling. Even though massive supercomputer power is available today, this issue remains because of the spits between the required global extent and the fine grid resolution, now reaching into the submesoscale parameter range. In lieu of unaffordable, routinely usable global high-resolution configurations, grid refinement approaches, nesting fine meshes within global grids of coarser resolution, can provide an alternative. It will be described how such nesting capabilities offer possibilities for cost-effective series of model experiments. By illustrating examples from the deepwater formation regions in the North Atlantic and the nonlinear interoceanic exchange in the Agulhas region south of Africa, it will be shown that nesting is more than a computational compromise to resolve the regional circulation. Through two-way interaction, it also allows to isolate regional feedback processes from key regions onto the large-scale and global circulation.

March 23, 11:20 (S5-10242)

Blue carbon ecosystems from South America: The role on carbon sequestration and mitigation of climate changes

Margareth **Copertino**

Instituto de Oceanografia, Universidade Federal do Rio Grande, Rio Grande, Brazil. E-mail: doccoper@furg.br

Vegetated coastal ecosystems - mangroves, tidal marshes and seagrass meadows – play an important global role in both the storage and sequestration of carbon that would otherwise remain as atmospheric CO_2, thereby contributing to climate change. Covering less than 2% of the marine bottoms, blue carbon systems capture and stock from 235 to 450 Tg C annually, which is equivalent to one third or half of the emissions from transport sector. Even providing an estimated USD $1.6 billion in ecosystem services annually and playing an essential role in the livelihoods and well being of billions of people, coastal areas are among the most threatened natural ecosystems on Earth. Emissions from clearing of blue carbon ecosystems can result in up to 900 million Ton CO_2 per year, which is about 2% of all anthropogenic GHG emissions. Ranking among the five largest GHG emitters, Brazil leads world in reducing emissions, due to efforts on public policies, better monitoring system and supply chain interventions. Deforestation of Amazon and Cerrado summed about 61% of the total Brazilian emissions (28 billion tCO_2e). However, rates of coastal degradation are unknown and the role of mangroves, salt marshes and seagrasses has been ignored by climate regulations, plans and policies. A recent group effort reviewed and synthesizes the knowledge on blue carbon systems across Brazil, analyzing their potential role on global climate mitigation, taking into account their intrinsic CO_2 sequestration capacity, and the potential for carbon emissions arising from deforestation and land use changes.

March 23, 11:55 (S6-10001)

Phenology responses of southern marine species to climate: Impacts and adaptation options

Lynda E. **Chambers**[1,2], Peter Dann[2] and Alistair J. Hobday[3]

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2 Phillip Island Nature Parks, Phillip Island, Australia
3 CSIRO Oceans and Atmosphere Flagship, Hobart, Australia

On a global scale, marine species are one of the most threatened groups, with the Southern Hemisphere over-represented in the numbers of these species of conservation concern. Understanding environmental and anthropogenic drivers of change has been the focus in recent decades, with climate change now an additional major threat to many populations. The drivers of phenological change in southern species vary, but are generally associated with changes in oceanographic conditions, with the extent and distribution of sea-ice playing an important role for more southerly species. Higher land surface temperatures may have a negative impact on breeding productivity through increased competition for breeding sites and heat-related stress for some species and locations. Conversely, for species such as the Little Penguin *Eudyptula minor* in south-eastern Australia, higher ocean temperatures correspond to increased productivity and higher first-year survival, at least in the short-term.

Given these observed changes, and future projections, methods to assess the best adaptation options in the face of climate change are needed. Fortunately there are a range of options for reducing vulnerability of colonial seabirds, however, options are more limited for other marine species. The focus of this presentation is on tools to evaluate and prioritize options before implementation of adaptation options, including technical merit, institutional barriers and social acceptability. Monitoring to evaluate effectiveness of adaptation option is critical, and should be a focus in any adaptation experiment, building upon the experience of researchers and managers charged with securing the future of these species.

March 24

March 24, 09:00 (S1-10000)

Multi-scale physical-biological interactions in the ocean – The importance of submesoscale processes

Paulo H.R. **Calil**

Laboratório de Dinâmica e Modelagem, Instituto de Oceanografia (FURG), Rio Grande, Brazil. E-mail: paulo.calil@gmail.com

Patterns of primary productivity in the ocean depend on an intricate relationship between physical, chemical and biological processes that occur on varied temporal and spatial scales. By controling the vertical and horizontal exchange between water masses and, consequently, the supply of limiting nutrients, these interactions modulate patterns of species composition and diversity observed in the ocean as well as the existence of biogeochemical provinces. Moreover, the supply of new nutrients into the euphotic zone ultimately controls export production which is a strong constraint to atmospheric CO_2 concentrations as it determines the amount which is absorbed by the oceans. Therefore, understanding physical-biogeochemical interactions in the ocean is vital in order to have a more complete view of the Earth's climate system. This effort requires marine scientists with various backgrounds to join efforts on multi-disciplinary projects, which are both observational and modelling challenges as processes operating at multiple spatial and temporal scales overlap. Here, I will illustrate the importance of submesoscale O(1-10km) and mesoscale O(10-100 km) processes on cross-frontal exchanges in various regions of the South Atlantic Ocean and propose sampling techniques to adequately infer their importance on the exchange of tracers.

March 24, 09:35 (S10-9907)

Forecasting climate change impacts on large pelagic fish populations and fisheries: Progress, uncertainties and research needs

Patrick **Lehodey**[1], Inna Senina[1], Simon Nicol[2], John Hampton[2], Anna Conchon[1], Anne-Cecile Dragon[1], Olivier Titaud[1], Beatriz Calmettes, Olivier Aumont[3], Morgane Dessert[3], Thomas Gorgues[4] and Christophe Menkes[4]

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High Seas pelagic fisheries target only a limited number of tuna species and billfishes (swordfish and marlins). The short-living skipjack tuna is the most tropical and productive species while bluefin tuna is the most temperate and long living species, providing small but extremely valuable levels of catch. A dozen of other exploited species share this oceanic habitat with other large predators, including sharks, and marine mammals, turtles and sea birds. Indeed, rather than a single habitat, these species have overlapping vertical and horizontal habitats defined by their preferences and tolerances developed over the evolution for several key physical and biological variables. Though some tuna and billfishes can move far in high latitudes searching for rich foraging grounds they all return to warm waters (roughly >24°C) for spawning, leading to seasonal migrations and complex population dynamics mechanisms interacting with several environmental variables. Therefore, characterizing habitats and projecting them in the future using IPCC scenarios is a useful but incomplete approach when investigating the impact of climate change on these species. The progress in the study of climate change impacts on tuna and associated species is reviewed with highlights on recent results based on a modeling framework developed to simulate the spatial dynamics of fish with mechanisms constrained by relationships based on the bio-physical environment predicted from coupled 3D models of ocean physics and biogeochemistry. This framework includes a Maximum likelihood Estimation approach allowing reconstructing past history of fish population, to dissociate fishing impacts from natural variability, and to forecast population dynamics under climate change scenarios.

March 24, 10:10 (S12-10002)

Looking back to go forward: Do past management actions foreshadow management responses to climate change?

Laura J. **Richards**[1], Robin M. Brown[2], James Christian[2] and Jake Rice[3]

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How will fisheries management agencies respond to climate change impacts on local or regional resources? In this talk, we argue that past actions by management agencies can provide insight into future actions. We also consider the work undertaken by some agencies to identify potential impacts, vulnerabilities and opportunities arising from climate change effects on fisheries and their associated ecosystems. These risks can be high over a medium-term (10-20 years) time horizon. Fisheries management agencies have significant experience with both abrupt and gradual changes to the availability of harvested resources. Based on specific cases of Canadian salmon and groundfish fisheries, we describe how a management agency could respond to abrupt short-term changes, for example through fishery closures, or to more gradual changes, such as through standardized operating procedures. To date, fisheries agencies appear less able to respond to an anticipated (and uncertain) future state when the time horizon is longer than about five years, much less than the time horizon required to address anticipated anthropogenic climate effects. Consequently, some current management decisions may not be resilient to climate change. We suggest opportunities to learn from the past to develop more robust management plans. Opportunities include clear communication products and adaptation tools, along with early engagement and dialogue among resource users, managers and scientists. We present examples of tested adaptation tools from the Canadian experience.

March 25

March 25, 09:00 (S2-9859)

Ocean acidification: Knowns, unknowns and perspectives

Jean-Pierre **Gattuso**

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Anthropogenic ocean acidification and global warming share the same primary cause which is the increase of atmospheric CO_2. Over the last two decades, ocean acidification has emerged as one of the threats to marine organisms and ecosystems. I will first review the current knowledge based on recent meta-analyses, reviews, and assessments. The effects on the past, present and future carbonate chemistry are known with a high degree of certainty. Most biological and ecological effects are much less certain although there is little doubt that calcification, primary production, behaviour, and biodiversity will be altered but with a magnitude that is not well constrained. These changes will in turn generate changes in the biogeochemical cycles, society and the economy. Whether these changes will be significant or not is also unknown. I will also highlight key research gaps and perspectives.

March 25, 09:35 (S8-9890)

Biodiversity consequences of climate change in the deep ocean

Lisa A. **Levin**

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Half of the planet's surface, and over 90% of its volume is covered by deep ocean below 200 m. This deep realm is highly connected to the surface ocean and accordingly experiences both natural and anthropogenically induced climate variation. Increasing heat content, reduced carbonate saturation, deoxygenation, and altered POC flux are among the deep manifestations of rising CO_2 in the atmosphere. We are just beginning to understand the implications for biodiversity and resilience in the deep sea, and both challenges and opportunities will be presented. Inference will be drawn from assemblage responses in the paleo record, from community patterns along strong natural gradients in the modern ocean, from recent faunal responses to shifting conditions and from experimentation. Upwelling margins provide outstanding model systems for evaluating the effects and interactions of multiple climate stressors on biodiversity. They exhibit dramatic T, CO_2 and O_2 gradients as well as expansion and shoaling of low-oxygen, low-pH waters in recent decades. Margin ecosystems will provide a template for discussing the functional consequences of changing macrobenthic biodiversity and their effects on ecosystem services. Examples will be drawn from tracer studies of carbon processing, colonization experiments to evaluate resilience, variance partitioning tools to examine climate stressor interactions and thresholds, and time series that reveal habitat compression and expansion. As human exploitation of the deep sea for food, energy and minerals introduces novel forms of disturbance, understanding the influence of climate change on function, resilience and recovery takes on added significance.

March 25, 10:10 (S11-10244)

From climate physics to coastal people: What do we know about climate change and its potential impacts on coastal populations?

Edward H. **Allison**

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How much do we know about the different pathways through which climate change is impacting and may further impact human societies living on or near the coast? The literature is replete with lists of ways climate change may affect the coastal environment but it tells us little about the relative importance of these different potential pathways of impact on people's health, livelihoods and wellbeing. This paper synthesizes and evaluates what is known about the impact of climate change on human societies living on or near the coast. The two most-studied pathways of impact are changes in fish production and distribution affecting the livelihoods and economies of fisheries and sea level rise and its potential (with storms) to damage coastal infrastructure and possibly to displace people permanently. Scientific understanding about ocean acidification, de-oxygenation, toxic algal blooms, diseases and invasive organisms are all increasing but we don't so far have any means for assessing the relative magnitude of these climate-change-driven threats from a human society perspective. Similarly, the research and policy communities have not yet considered indirect effects due to adaptation in other sectors–for example the impacts of flood control infrastructure on deltaic ecologies and societies. I conclude with a suggested agenda for policy-relevant research on climate change impacts, to better connect the growing body of biophysical research with a fragmented literature on social and economic impacts to develop a cohesive account of the impacts of climate change on societies living on the margins of the world's oceans and seas.

March 27

March 27, 09:00 (S3-10023)

Bio-essential and pollutant trace metals in a changing Atlantic Ocean

Micha J.A. **Rijkenberg**

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Anthropogenic influences on the distribution, and biogeochemical cycling, of trace metals in the oceans are evident since the industrial revolution. Toxic metals (lead and mercury) were emitted in large volumes leaving detectable signals in today's oceans. Results from the GEOTRACES program show that lead concentrations in the Atlantic have declined due to increased regulations, but not in areas where leaded fuel is still used like in the southern Mediterranean. Deep North Atlantic waters, intermediate waters and surface waters are enriched in anthropogenic mercury showing that deep water formation is an important sink for anthropogenic surface Hg. With constant or decreasing deep water formation, future increases in Hg emissions may therefore disproportionately enrich the surface ocean. The influence of climate change, including ocean acidification, on trace metals in the oceans is still largely unknown, due to the difficulty in ascertaining the effects of warming and acidification on the interaction between marine biota and trace metals. We are particularly interested in understanding the consequences of climate change on the biogeochemical cycle of iron. Iron regulates the carbon cycle by limiting primary production and nitrogen fixation. Conversely, it is the anthropogenic change in the carbon cycle that affects the biogeochemical cycle of iron. We use the GEOTRACES iron results in the Atlantic Ocean and adjacent basins to discuss how changes in atmospheric, hydrographic, chemical and biological processes may affect the biogeochemical cycle of iron and determine its future distribution.

March 27, 09:35 (S7-10021)

Predicting evolutionary responses to climate change in the sea: Progress and challenges

Philip L. **Munday**

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There is an increasing appreciation of the need to consider evolutionary responses when predicting the impacts of climate change on marine ecosystems, yet relatively few studies have tackled this critically important question. In part, this lack of research effort stems from a lack of understanding about how evolutionary responses can be tested and included in climate change models. In this talk I will explain why an evolutionary perspective is crucial to understanding climate change impacts in the sea. I will then discuss the different approaches that may be useful for addressing this challenge and examine progress that has been made to date. I will first examine evidence that phenotypic plasticity may assist marine species to persist in a rapidly changing climate. I will then outline the various experimental approaches that can be used to estimate evolutionary potential, focusing on molecular tools, quantitative genetics, and experimental evolution. I will describe the benefits of each approach and how they can be combined to gain a deeper understanding of evolutionary potential. Recent examples and a summary of current state-of-knowledge will be presented.

March 27, 10:10 (S9-10247)

Going nowhere or moving on: How do changes in species distribution impact marine food webs?

Coleen L. **Moloney**

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Physical and chemical changes in the marine environment cause changes in the locations of preferred habitats of living marine organisms. The impacts of these changes can propagate through the food web, affected by the fluidity of the habitats, their three-dimensional structures, and the variable importance to different components of the food web of processes operating across a range of time and space scales. There have been at least two marked changes in the Benguela eastern boundary upwelling ecosystem over the past few decades, one off Namibia (in the northern Benguela) and one off South Africa (in the southern Benguela). Off Namibia, once-productive small pelagic fish populations currently are a small fraction of their historical sizes, there has been an apparent proliferation of jellyfish in the ecosystem, and there have been marked reductions in populations of top predators. Many of these changes have been related to vertical structures and processes in the water column. In contrast, off South Africa, there have been poleward and eastward changes in horizontal distributions of a number of species, with probable alterations in food web dynamics. These different ecosystem changes have been explained variously by overfishing, spatially-biased fishing mortality and changed environmental conditions under climate change. This presentation will describe and contrast the changes in these ecosystems in terms of vertical and horizontal dimensions of the coastal ocean, review the evidence supporting different hypotheses of causes of change, and identify some issues that require further study.

S1 Oral Presentations March 24
Role of advection and mixing in ocean biogeochemistry and marine ecosystems

March 24, 11:20 (S1-10136), Invited

Wave-induced turbulence: Theory and practice

Alexander V. **Babanin**

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Marine biogeochemistry and ecosystems are closely connected with the physical processes in the upper ocean. Among such dynamics, ocean missing is one of the most important. Until recently, turbulence produced by the orbital motion of surface waves was not accounted for, and this fact limits performance of the models for the upper-ocean mixing and air-sea interactions.

Theory and practical applications for the wave-induced turbulence will be reviewed in the presentation. Traditionally, wave effects are only attributed to the wave breaking and parameterized through the surface fluxes of the energy and momentum.

Physically, the wave breaking turbulence penetrates the water depth at the scale of wave height and then needs to be diffused down in order to participate in the ocean mixing. In the meantime, the non-breaking wave turbulence is depth-distributed at the scale of wavelength. This scale is of the order of 100 m and is comparable with the mixed layer depth. Therefore, such turbulence does not need additional assumptions, diffusion or advection in order to mix the seasonal ocean layer through the thermocline below. In this regard, a key step in linking this knowledge to the ocean mixing models is to express the non-breaking wave-induced vertical mixing analytically, as a function of wave spectrum which can be estimated from a coupled wave numerical model. The turbulence production due to waves has been successfully used in climate, ocean-circulation, sediment suspension models, with significant improvements to the simulations. Therefore, the traditional perception of the shear induced mixing being the main source of vertical mixing, may need to be revised, and in any case this important extra source of turbulence in the wave-affected areas has to be included.

March 24, 11:50 (S1-10143)

Variability of the North Equatorial Current (NEC) and its implications on Japanese eel larval transport

Huijie **Xue**, Ango Hsu and Fei Chai

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Numerical Lagrangian experiments were conducted to study the effects of NEC strength and position on Japanese eel larval migration in the western North Pacific. Particles were released from the grid points that cover Japanese eel spawning area and from different depths during the spawning seasons of years 1991-2010, and the percentages of particles that reach the coastal areas of Taiwan were calculated. More particles reach Taiwan when the transport of the NEC is stronger as the particles are able to travel through NEC and to enter the Kuroshio more quickly. When the NEC transport is strong high percentages of particles that reach Taiwan come from the northern part of the spawning area, while when the transport is weak they come more evenly from the entire spawning area. On the other hand, no apparent correlation was found between the NEC bifurcation latitude and the average percentages of particles transported to Taiwan. Since the NEC is regulated by wind forcing in the tropical western Pacific, the interannual and decadal variability of successful Japanese eel larval migration are thus related to ENSO events and to the climate variability.

March 24, 12:10 (S1-10048)

Temporal evolution of marine biogeochemistry in Large Marine Ecosystems

Julien **Palmiéri**, Andrew Yool and Ekaterina Popova

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Large Marine Ecosystems (LMEs), are large coastal and shelf areas that annually produce ~95% of the global fish catch. LMEs have been defined to help the management of these areas, and improve their sustainability. Many studies have already investigated the current state of these ecosystems. These have determined that the main factors responsible in a change of biomass yields are i) excessive exploitation; ii) coastal pollution; and iii) shift in climate regime. The latter is expected to become significantly more important during this century.

In this study we focus on climate factors, by modelling climate change (IPCC-RCP8.5) impacts on the biogeochemistry of LMEs across the 21st century.

The first part of this study evaluates our dynamical-biogeochemical coupled model NEMO-MEDUSA2 in the LMEs under the current climate for 2 different resolution

configurations (1° and 1/4°). This analysis determines the LMEs for which resolution is most significant, and explains which physical processes have been improved or degraded by increased resolution, as well as the resulting impact on biogeochemistry.

Next, the future physical and biogeochemical evolution of LMEs is analysed under climate change. Globally, the model predicts a decrease of primary production in most LMEs, except in high latitudes. This global productivity decrease can be attributed regionally either to ocean warming, or to freshening of sea surface water. These processes induce an elevated stratification of surface waters and, hence, a diminution of nutrient transport from deep to surface warters. The potential impact of this change for regional fisheries is also explored.

March 24, 14:00 (S1-9854)

The fundamental role of the surface wave in the ocean and climate systems

Fangli **Qiao** and Zhenya Song

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Most of ocean general circulation models (OGCMs) have faced common problems in simulating the upper ocean, such as the simulated sea surface temperature (SST) is overheating, the subsurface temperature is too cold and the upper ocean mixed layer depth (MLD) is too shallow especially in summer, which is believed that these problems are caused by insufficient vertical mixing in the upper ocean. As the ocean is flywheel of climate system, the coupled ocean-atmosphere general circulation models (CGCMs) also face some common challenges, such as tropical biases, too shallow MLD in the Southern Ocean *etc*. As the oceanic mixing process is essentially an energy balance problem, waves, as the most energetic motions at the ocean surface, should play a controlling role. The surface wave breaking can enhance mixing in the upper ocean is well accepted. Although show some improvements on ocean circulation models, the mixing effects of the wave breaking are too weak and limited in the top few meters, in the order of wave height. Based on the idea of oceanic multi-scale interaction, *Qiao et al.* (2004) introduced the non-breaking wave-induced vertical mixing Bv, which can be calculated from a wave numerical model, and tested in series global OGCMs including POM, MOM4, ROMS, POP, HIM and NEMO *etc.*, all show similar improvements in the simulation of the upper ocean. Compare with breaking wave-induced mixing, Langmiur circulation, and traditional shear-induced vertical mixing, Bv plays much dominant role than all three above.

March 24, 14:20 (S1-9881)

Temporal and spatial variability of carbon cycle in the northwestern Pacific Ocean: A three-dimensional physical-biogeochemical modeling study

Xuanliang Ji, Guimei Liu and Shan **Gao**

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As a main stock of CO_2, ocean plays an important role in controlling CO_2 in atmosphere, mitigating the greenhouse effect and adjusting the global climate. A three dimensional physical-biogeochemical model including carbon cycle, coupled with Regional Ocean Modeling System (ROMS) is established to investigate the physical variations, ecosystem responses, and carbon cycle consequences in the northwestern Pacific Ocean (NWP). The model is driven by daily air-sea fluxes derived from the National Centers for Environmental Prediction (NCEP) reanalysis from 1982 to 2005. The NWP domain-averaged monthly pCO_2^{sea} varies between 350 and 420µatm with the highest value in August and lowest value in January. The increasing rate of pCO_2^{sea} is about 1.11µatm yr^{-1}. However, pH indicates an opposite tendency, with a decreasing rate 0.0010 yr^{-1}. The pCO_2^{sea} has a positive correlation with SST, and a negative correlation with Chl-*a*. According to the sensitivity experiment, the major controlling factor of pCO_2^{sea} in NWP is biological activity, and the SST is the second. The 24-year mean air to sea CO_2 flux averaged over the entire NWP is 0.12mol m^{-2} yr^{-1}, indicating that the NWP is a sink of CO_2 to atmosphere. Meanwhile, the NWP domain-averaged monthly CO_2 flux varises from -1.25 to 1.52mol m^{-2} yr^{-1} with the lowest value in summer and highest value in winter. The inverse relationship between the interannual variability of air-sea CO_2 flux and NINO3 SST index indicates that the carbon cycle has a good connection with El Nino-Southern Oscillation (ENSO) phenomenon.

March 24, 14:40 (S1-10084)

Effects of dynamical processes on primary production and phytoplankton biomass in the Pacific subtropical-tropical zone

Eliana **Gómez Ocampo**[1], Emilio Beier[2], Gilberto Gaxiola-Castro[1] and Mario A. Pardo[2]

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Because of the importance of physical dynamics on the availability of light and nutrients in the euphotic zone for the phytoplankton growth and their possible shifts with climate change, our goal is to estimate the physical forcing effects over the phytoplankton biomass (Chl-*a*) and primary production (PP) in the tropical-subtropical zone of the northeastern Pacific Ocean. We combine *in situ* and satellite observations in several Generalized Additive Models (GAMs) which explain the variability of water-column integrated PP and Chl-*a* (PP_{int}, Chl_{int}). We took into account some variables characteristics of dynamic processes as the Absolute Dynamic Topography (ADT), Mixed Layer Depth (MLD), and variables derived from wind components. Monthly Chl_{int} variability was explained by ADT (D^2= 8%) and north-south wind stress component (NSwnd) (D^2= 3%). PP_{int} was explained by ADT (D^2= 7.3%), MLD (D^2= 7%) and wind speed (W) (D^2= 4%). We observed that ADT has a predominant effect on Chl_{int} and MLD on PP_{int}. When ADT drops and W increases, larger maximum of Chl_{int} occurs. Higher PP_{int} occurs when match the decrease of ADT (below 60 cm) with shallower of MLD is (below 25 m). Phytoplankton photoacclimation to light and turbulence in the water column is related with MLD, and ADT is related with nutrient availability. California Current has showed tendency to increase in PP and Chl-*a* in last years. This study will help to understand some processes that regulate its distribution and understand why PP and Chl-*a* can be sensitive to climate variability and change in this area.

S1

March 24, 15:00 (S1-9920)

How does horizontal mixing affect the primary production on the Faroe Shelf?

Sólvá Káradóttir **Eliasen**, Bogi Hansen, Karin Margretha Húsgarð Larsen and Hjálmar Hátún

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The Faroe Islands are surrounded by a shelf with tidally mixed water, partly isolated from the open ocean by a tidal front. The on-shelf areas support a relatively uniform shelf ecosystem, distinct from the off-shelf waters. Earlier studies have shown high inter-annual variability in biological production on-shelf, with high correlation between fluctuations in the various trophic levels. It seems as if phytoplankton production is the prime driver in the ecosystem since grazing pressure by the zooplankton community during the spring bloom is not large enough to postpone and/or suppress the phytoplankton spring bloom. This indicates that physical effects are the dominant control of the primary production on the Faroe Shelf. For a well-mixed shelf water mass, solar radiation is an obvious candidate as a controlling factor, but inter-annual variations in light intensity show no correlation with primary production. Instead, it appears that variations in the horizontal exchange rate between on-shelf and off-shelf waters can explain variations of the spring bloom on-shelf. Two competing forcing factors seem to control the exchange rate: the homogenizing tidal currents and the air-sea heat input, which tends to induce both vertical and horizontal density gradients across the tidal front. Based on heat-flux data, temperature data, salinity data and precipitation data the exchange has been estimated and these results are discussed and linked to tidal currents and to variations in the primary production.

March 24, 15:20 (S1-10035)

Iron supply to the Southern Ocean mixed layer from below: The ocean model effect

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In the Southern Ocean, iron plays a key role in limiting biological production. Studies of the iron supply to the surface mixed layer have traditionally focused on the aeolian and sediment contributions, but recent work has highlighted the importance of the vertical supply from below. We have performed a model study in which the biogeochemical model REcoM2 was coupled to two different ocean models, the Finite Element Sea-ice Ocean Model (FESOM) and the MIT general circulation model (MITgcm) and analyzed the magnitude of the iron sources from below in the two models.

Our results revealed a remarkable difference in terms of mode and magnitude of transport; the mean iron supply from below in the Southern Ocean was on average four times higher in MITgcm than in FESOM. The dominant pathway was entrainment in MITgcm, whereas diffusion dominated in FESOM. We discuss how the difference in the depth and seasonal amplitude of the mixed layer between the models has a major effect on the vertical iron profile and thereby also on the iron fluxes. A further effect of the difference in supply is that the fraction of exported net primary production is higher in MITgcm than in FESOM, showing that the choice of ocean model has a significant impact on the modeled carbon cycle in the Southern Ocean, with possible implications for model runs predicting the future carbon uptake in the region.

March 24, 16:10 (S1-10130)

Modeling impacts of mesoscale eddies on biogeochemical processes in the South China Sea

Fei **Chai**[1], Huijie Xue[1], Peng Xiu[2] and Mingxian Guo[3]

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Numerous mesoscale eddies occur each year in the South China Sea (SCS), but their statistical characteristics and impact on biogeochemical cycles have never been substantially investigated. A Pacific basin-wide three-dimensional coupled physical-biogeochemical model (ROMS-CoSiNE) has been developed and the results for the SCS are used to quantify the eddy activities and the subsequent biogeochemical responses during the period of 1991-2007. A total of 519 mesoscale eddies with lifetimes longer than 30 days was used in the statistical analysis. Composite analyses reveal that cyclonic eddies are associated with abundance of nutrients, phytoplankton and zooplankton while anticyclonic eddies depress biogeochemical cycles. Diatoms are dominant in phytoplankton species due to the abundance of silicate in cyclonic eddies. Dipole structure of vertical nutrient fluxes with net upward motion in cyclonic eddies and downward motion in anticyclonic eddies were also detected. During the eddy lifetime, planktons grow and the composition of the community is adjusted by the predator-prey relationship in cyclonic eddies. This modeling study suggests that mesoscale eddies and associated sub-mesoscale processes in the SCS are important sources of nutrients (nitrate and silicate) to the euphotic zone, which plays a significant role in regulating the biogeochemical cycle in the SCS.

March 24, 16:30 (S1-10046)

Future change in ocean productivity: Is the Arctic the new Atlantic?

Andrew **Yool**, Ekaterina Popova, Julien Palmiéri and Andrew C. Coward

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One of the strongest and most persistent features in open ocean productivity is the North Atlantic spring bloom. In response to seasonal increases in irradiance and water column stratification, phytoplankton populations rise significantly in surface waters, a pattern that visibly tracks polewards as seasonal changes tip into summer. While blooms also occur in the Arctic Ocean, their progress is constrained by sea-ice and the strong vertical stratification that characterises this region. However, Arctic sea-ice cover is currently in decline, and climate forecasts suggest this will continue, with possibly completely ice-free summers by the mid-21st century. Such a change may open the Arctic up to spring blooms of the kind currently found in the North Atlantic, and do so at the same time as Atlantic productivity is threatened by climate change-driven ocean stratification. Here we use a high-resolution coupled ocean-biogeochemistry model, NEMO-MEDUSA, to investigate productivity in both regions from the present to the future. Drivers of present-day patterns are identified, and changes in these across a climate change scenario (IPCC RCP8.5) are simulated and analysed. We find a globally-significant decline in North Atlantic productivity (>20%) by 2100, as well as a correspondingly significant rise in the Arctic (>50%). We investigate, in particular, whether the simple view that the future Arctic is merely "copying" the current North Atlantic is correct, or whether unique aspects of the Arctic's seasonal hydrography and biogeochemistry are more important. We also examine the significance of these changes on the sustainability of aquatic resources.

March 24, 16:50 (S1-10077)

Submarine Groundwater Discharge revealed by radium isotopes (Ra-223 and Ra-224) near a paleochannel on the Southern Brazilian continental shelf

Karina Kammer **Attisano**[1], Isaac Rodrigues Santos[2], Carlos F.F. de Andrade[1], Mariele Lopes de Paiva[1], Idel Cristina Bigliardi Milani[3] and Luis Felipe Hax Niencheski[1]

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Submarine Groundwater Discharge (SGD) has been recognized as an important component of the ocean-continent interface. The few previous studies in Brazil have focused on nearshore areas. This paper explores SGD on the Southern Brazilian Continental Shelf using multiple lines of evidence that include radium isotopes, dissolved nutrients, and water mass observations. The results indicated that SGD may be occurring on the Continental Shelf in the Albardão region, near a paleochannel located 50 km offshore. This paleochannel may thus be a preferential pathway for the delivery of nutrient- and metal-enriched groundwater and porewater into continental shelf waters.

March 24, 17:10 (S1-10078)

To what extent does iron advection affect the inter-annual variability of Southern Ocean island blooms?

Josie **Robinson**[1,2], Ekaterina Popova[2], Meric Srokosz[2] and Andrew Yool[2]

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Iron-rich shelf water advected downstream from landmasses plays a crucial role in the formation of the largest annual phytoplankton blooms within the Southern Ocean. Here we investigate and compare the blooms that form around three major island systems in the Southern Ocean: the Kerguelen Plateau, the Crozet Islands and South Georgia. Using composite satellite data from the ESA Ocean Colour Climate Change Initiative for the period 1998-2007, we study the inter-annual variability in the seasonal blooms, and investigate their cause using Lagrangian particle tracking. Lagrangian particles are released monthly from each islands' shelf region, and advected using velocity data from the state-of-the-art NEMO 1/12° ocean general circulation model. The particles are used to represent iron-rich shelf water, and test the hypothesis that the dispersal of this micronutrient is responsible for the spatio-temporal bloom patterns observed around the islands. For each simulated year, particle positions in the month preceding the start of the bloom are analysed and compared with the extent of the corresponding satellite-observed bloom. The average annual percentage of bloom area overlapped by trajectories (in the month preceding the bloom) is 76% (σ ±8%) for Kerguelen; 36% (σ ±9%) for Crozet; and 56% (σ ±10%) for South Georgia. By studying the trajectory overlap of the bloom for individual monthly releases, analysis has also quantified the inter-annual variability driven by the local circulation. It is vital to understanding iron transport and its control over biogeochemistry under current physical conditions, in order to deduce the impact of climate change.

March 24, 17:30 (S1-10015)

Importance of advection to form a climate and ecological hotspot in the western North Pacific

Shin-ichi **Ito**[1], Taku Wagawa[2], Shigeho Kakehi[2], Takeshi Okunishi[2] and Daisuke Hasegawa[2]

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Recently two quasi-steady jets bifurcate from the Kuroshio Extension were found. We conducted hydrographic and mooring observations of the western quasi-steady jet. The direction of the jet was steady in east-north-east through a year and the position migrates southward in winter. The annual averaged transport was estimated as 8 Sv. The jet flows parallel to the subarctic current and horizontally entrains the nutrient rich subarctic water. Additionally, the warm and saline water transported by the quasi-steady jet possibly contribute to deep wintertime mixed layer formation and hence nutrient rich water is supplied from the deep layer to the surface. These horizontal and vertical nutrient supplies resulted in high primary production that possibly creates an offshore ecological hotspot in the western North Pacific. Autumn bloom of phytoplankton was detected in the region 43-45N and 158-166E from the satellite data. This area corresponds to the termination of the jet. Indeed, there is a nursery ground of small pelagic fishes in that region. Other studies indicated the importance of strong sea-surface temperature front along the jet to form a climate hotspot. The strength of the quasi-steady jet showed decadal variability accompanied with the meridional shift of the Kuroshio Extension. It is still unclear how the decadal fluctuation of the quasi-steady jet influence on the formation of the climate and offshore ecological hotspot and hence on the recruitment of the small pelagic fish. It is a big challenge for us to investigate impacts of fluctuations in limited local key areas to large marine ecosystems.

March 24, 17:50 (S1-9911)

The performance of a z-level ocean model in modeling global tide

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In recent years, global tide begins to be solved explicitly in the OGCM and the climate models, however not all of these models ensure global forward tide solutions of reasonable accuracy. As the first step towards inserting tide into our global wave-circulation coupled model, we show that with reasonable data preparation, model configuration and inclusion of internal tide drag parameterization the Z-coordinate ocean model (equipped with bottom partial cells) is able to reproduce reasonably accurate global barotropic tide without utilizing data. Based on the code of MOM4, we simulated global barotropic tide in horizontal resolution of 1°, 1/2° and 1/4°. Comprehensive sensitive experiments are conducted to test the horizontal and vertical resolutions, construction of model topography. Consistent with the previous studies, we found that additional dissipation terms is needed to reduce the inordinately large energy, thus internal tide drag parameterization(IT drag terms) proposed by Jayne and St. Laurent (2001) is adopted. With inclusion of IT drag terms and κoptimally tuned, our model succeeds to reproduce global tide simulation of reasonable accuracy, the elevation RMS error compared with TPXO7.2 for M2 is 8.5cm. Without IT drag term the tidal energy is dissipated mainly in shallow water where tidal flow is large, with inclusion of IT drag term additional tidal dissipation appears in the deep sea where topography is rough which is closer to the actual scenario in the ocean.

S2 Oral Presentations, Day 1 March 25
Ocean acidification

March 25, 11:20 (S2-10075), Invited

Progress and prospects on ocean acidification research of the Tropical South Atlantic

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The study of ocean acidification only recently got a significant impulse in the Brazilian scientific community. The initiatives are related to biogeochemistry processes and the balance of CO_2 in sea-air interactions and ocean circulation, impacts of acidification in the Biosphere, from organisms to ecosystems, and studies of natural archives and proxies of pH. National research networks now investigate CO_2 system in the ocean and in the atmosphere and interact with global initiatives such as PIRATA. Buoys with real-time CO_2 system measurements will be moored in the Equatorial Atlantic and an equipment to measure CO_2 fugacity was developed. In the last two years, CO_2 system variation trends, from estuaries and bays to the continental shelf, are also monitored in the Tropical coast of Brazil. Modeling and observational projects are now investigating CO_2 system in the subtropical and polar Atlantic. Microcosm facilities are thriving so that projects assessing the response of organism metabolism to different pH states are underway. Flow-through mesocosm facilities, indoor and outdoor, in tropical and subtropical conditions, were built and some experiments involving the response of corals and coralline algae were concluded. Reliability of natural archives and proxies, especially corals, is being tested. The study of the circulation and CO_2 flux in the Tropical/Equatorial region is crucial to understand its contribution to CO_2 balance. It is already known that the Tropical Atlantic is a source of CO_2 to atmosphere but specific regions in the proximity of large rivers discharge such as the Amazon River may act as CO_2 sink. Besides the effect of pH lowering on calcification, the basal metabolic responses of these organisms must be understood. Among the important carbonate environments, reefs developed under marginal turbid conditions in the Western South Atlantic. Reef growth has an important contribution of crustose coralline algae, along with corals. The lowering of pH, together with the increase of thermal anomaly events might have a disastrous effect in its conservation.

S2

March 25, 11:50 (S2-9866)

Effective CO_2 utilization in response to increasing CO_2 levels in natural phytoplankton assemblages from the coastal Bay of Bengal, India

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In the contemporary oceans, dissolved CO_2 is quite low with predominance of HCO_3^- and the caboxylating enzyme Rubisco fixes only CO_2 as a substrate. Hence, to maintain steady state photosynthesis, many phytoplankton possess a carbon-concentration mechanism (CCM): a biophysical technique for pumping HCO_3^- inside the cell followed by enzymatic conversion to CO_2 in the vicinity of Rubisco. Our study area, Bay of Bengal (BoB), show high variability in dissolved CO_2 levels in its surface waters and a series of microcosm experiments were conducted under different CO_2 levels to see if natural variability of dissolved CO_2 has any impact on phytoplankton physiology and growth. Increased photosynthetic rate and organic matter production was observed in the high CO_2 treated samples than that of the low CO_2. $d^{13}C_{POM}$ showed a significant reverse correlation with CO_2 levels indicating the possibility of higher dissolved CO_2 intake in response to increasing CO_2 supply. During the 24 hours incubation experiment, higher $\delta^{15}N_{POM}$ values were observed in the low CO_2 treatments relative to the high CO_2 levels, which presumably, due to higher nitrogen utilization in order to synthesize all necessary components for running an active CCM. It is likely that, under low CO_2 levels, phytoplankton might operate an active HCO_3^- uptake to maintain steady state photosynthesis. Increasing CO_2 levels may accelerate diffusive CO_2 supply inside the cell leading to increased CO_2 fixation restricting the cell from energetic loss related to CCM operation. Hence, the natural CO_2 variability can potentially influence phytoplankton growth and carbon metabolism in this bay.

March 25, 12:10 (S2-9943)

Effects of elevated *p*CO_2 and temperature on prokaryotic community composition and respiration in mesopelagic waters of the NW Mediterranean Sea

Markus **Weinbauer**[1,2], Chiaki Motegi[1,2], Jinwen Liu[3], Cornelia Maier[1,2], Maria-Luiza Pedrotti[1,2], Minhan Dai[3] and Jean-Pierre Gattuso[1,2]

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pCO_2 levels in the mesopelagic are higher than in surface waters and it has been established that the dark ocean of the Mediterranean Sea has been already subject to an increase in temperature. We investigated the effects of elevated *p*CO_2 and temperature on prokaryotic community composition (PCC) and respiration (PR) variables in long-term (2 months) experiments with mesopelagic waters (300m depth) collected off the Bay of Villefranche, NW Mediterranean. Two experiments were conducted with two temperatures (13º and 16ºC) and two *p*CO_2 levels (ambient *p*CO_2 , 400 atm; elevated *p*CO_2, 1000 atm). PCC was assessed as 16S rRNA gene based denaturing gradient gel electrophoresis. In the first experiment, bacterial community composition clearly differed between control and elevated temperature. At elevated temperature, the bacterial community different between the two *p*CO_2 levels. In the second experiment, both bacterial and archaeal communities responded to changes in temperature, but bacterial community clearly differed between the two *p*CO_2 levels at control temperature. This could be due to the different initial PCC present. Bacterial and archaeal phylotypes showed no consistent trends between experiments. Overall, we found that 1) temperature and *p*CO_2 changes can potentially affect community composition, 2) higher temperature rather stimulated whereas elevated *p*CO_2 levels rather repressed PR, 3) temperature changes had a stronger effect on prokaryotic community composition and PR, and 4) and rather subtractive than additive effects were observed.

March 25, 14:00 (S2-9789)

Coccolithophores, calcification and ocean acidification

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Marine calcifying phytoplankton (coccolithophores) represent the most productive pelagic calcifiers in the modern ocean and numerous studies have indicate the severe effects of ocean acidification on the biogenic precipitation of calcium carbonate in coccolithophores. However, one of the most fundamental question on coccolithophore calcification is still unanswered: What triggered a calcification mechanism in coccolithophores and to which function? Here, I will present conclusive results from laboratory experiments which can explain the evolutionary reason behind coccolithophore calcification. Furthermore, I will elucidate these findings in regard to ocean acidification and our current understanding of coccolithophore ecology.

March 25, 14:20 (S2-10266)

pH monitoring in the upper Gulf of Thailand and effect on early development and settlement of corals, *Acropora millepora* and *Pocillopora damicornis*

Suchana **Chavanich**[1], Wipada Lalitpattarakit[1], Narainrit Chinfak[1], Suppakarn Jandang[1], Pataporn Kuanui[1], Somkiat Khokiattiwong[2] and Voranop Viyakarn[1]

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Water qualities including pH, temperature, salinity, DO, and nutrient were monitored in the upper Gulf of Thailand. In addition, the experiments were conducted to investigate the effect of reduction of pH on early development and settlement of corals, *Acropora millepora* and *Pocillopora damicornis*. Three different pH levels (pH = 7.6, 7.9, 8.1) were conducted. Treatments of the experiments consisted of exposing embryos and larvae of 2 coral species in different pH levels. Then, changes of embryo and larval morphologies were observed under different pH conditions. The field monitoring showed low fluctuation of seawater environmental parameters. However, the results from the experiments showed that changes of pH levels led to the reduction of the fertilization rates of corals and increasing the numbers of abnormal embryos and larvae of corals. In addition, the settlement rates of coral larvae differed between pH treatments. When lowering pH, the settlement rates of larvae were decreased. In addition, acidification led to the delay and incompletion of larval metamorphosis. Our results suggested that there was a negative effect on *A. millepora* and *P. damicornis* under the decrease of pH.

March 25, 14:40 (S2-10139)

Effects of ocean acidification on crustacean zooplankton: A comparison of the copepod *Calanus pacificus* and the krill *Euphausia pacifica*

Anna K. **McLaskey**[1], Julie E. Keister[1], Paul McElhany[2], M. Brady Olson[3], Brooke A. Love[3], Amanda K. Winans[1], D. Shallin Busch[2] and Mike Maher[2]

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Despite their critical importance in marine food webs, little ocean acidification (OA) research has focused on crustacean zooplankton; however, our findings suggest that some groups may be impacted in the near future. *Calanus pacificus* and *Euphausia pacifica* are two particularly important species throughout the north Pacific and the California Current Ecosystem, where OA is rapidly increasing. Our laboratory tests on the development of these species under OA conditions indicate that *E. pacifica* is more sensitive than *C. pacificus*, with significant effects at relatively low pCO_2 concentrations compared to conditions they currently experience. A significant but small decline in *C. pacificus* development occurred at 1200 µatm pCO_2, reduced hatching at 2200, and reduced survival at 3000, indicating that *C. pacificus* is not particularly sensitive to near-future OA. In contrast, although *E. pacifica* hatching was robust to very high pCO_2, development and survival in just the first five larval stages were reduced by as much as 20% at 950 µatm pCO_2. These results are surprising given the naturally high pCO_2 environment these populations currently experience and have profound implications for future populations.

March 25, 15:00 (S2-9885)

Behavioural and physiological responses of the estuarine bivalve *Macoma balthica* from the Baltic Sea to increased CO_2 concentration

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Managing ecological risks from increased seawater CO_2 partial pressures and a subsequent decline in pH in marine environment remains an important challenge. Atmospheric carbon dioxide continues to rise and ocean acidification is predicted to affect various ecological formations in different zoogeographical zones. The impact of high CO_2 concentration can be particularly evident in water basins which are subject to other abiotic stressors, including eutrophication and anthropogenic pressure, such as the Baltic Sea.

In this study short- (days) and medium-term (weeks) biological consequences of increased CO_2 concentration in water were quantified for the Baltic clam *Macoma balthica* – one of the dominants on deep soft bottom in the Baltic. In a flow through system, the bivalves were allowed to burry in sediments and were exposed to four CO_2 levels: 400 ppm (control), 1000 ppm, 2000 ppm and 10000 ppm corresponding to pH 7.7, 7.3, 7.0 and 6.3, respectively *i.e.*, covering a range of CO_2 concentrations predicted in the future. One feeding regime (8167 phytoplankton cells cm^{-3}) was applied to all treatments under stable salinity (7.0) and temperature (10°C) conditions. Basic geochemical (T, O_2, total alkalinity, sediment pH profile) and biological responses were determined in five replicates at time-points of -4 weeks (before 30-day acclimation period), 0-day (after acclimation) and then 1, 2, 4, 6 and 8 weeks after CO_2 induction. The impact of low pH water on bivalves was assessed through measuring selected behavioural indicators (mortality, burrowing depth) and physiological markers (growth rate, energetic budget, content of biochemical compounds and respiration rate).

March 25, 15:20 (S2-9989)

Combined effects of seawater acidification and Arsenic in *Crassostrea gigas* and *C. angulata*: Oxidative stress and biomineralization enzymes activity assessment

Anthony **Moreira**[1], Etelvina Figueira[1], Ângela Almeida[1], Iracy L. Pecora[2], Amadeu M.V.M. Soares[1] and Rosa Freitas[1]

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Seawater acidification is of major concern particularly for calcifying marine invertebrates. The decrease of both pH and carbonate mineral saturation, have shown to interfere with shell mineralization processes for a wide range of calcifying organisms. Also, interactions between pH alterations and other stressors, such as metals and metalloids, may alter the toxicity of these compounds towards organisms. Despite the increasing concern on this topic, few studies have assessed these interactions, and in the case of Arsenic (As) one of the most ubiquitous contaminants worldwide, there is a lack of published information regarding the toxicity of this metalloid under an ocean acidification (OA) scenario using bivalve species.

Here, we assessed the performance of two closely related oyster species, *Crassostrea gigas* and *C. angulata*, under an OA scenario in combination with As exposure. This allowed the comparison of the oysters biochemical responses between an exotic, worldwide distributed species (*C. gigas*) and a native oyster species to Portugal (*C. angulata*), when exposed to these stressors. Both species were submitted to a chronic exposure assay, consisting on an acidification experiment (control pH and ΔpH=-0.5), combined with As exposure (4 mg As.L^{-1}). After the experiment, the activity of shell formation related enzymes were assessed, namely carbonic anhydrase and alkaline phosphatase. Oxidative related parameters such as lipid peroxidation and the activity of antioxidant enzymes (Glutathione S-Tranferase, Glutathione S-Transferase Omega, Catalase and Superoxide dismuthase) were also studied, bringing new insights on the response of bivalves to the combined effect of OA with As exposure.

March 25, 16:10 (S2-10158)

Ocean acidification alters marine invertebrate behaviour via neural impairment

Sue-Ann **Watson**[1], Blake L. Spady[1], Sjannie Lefevre[2], Paolo Domenici[3], Göran E. Nilsson[2] and Philip L. Munday[1]

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Ocean acidification poses a range of threats to marine invertebrates including reduced growth and calcification. However, the potential effects of rising CO_2 on marine invertebrate behaviour are largely unknown. Here we show that projected near-future seawater CO_2 levels (~600, ~950µatm) alter marine invertebrate behaviours. In squid, elevated-CO_2 increased activity ~3-fold and altered their behavioural strategies when startled, with more squid choosing escape and inking at elevated-CO_2, compared with threat responses at control-CO_2. In gastropods, elevated-CO_2 impaired escape behaviours during predator-prey interactions. Conch snails normally leap backwards rapidly when faced with a predator. However, elevated-CO_2 halved the number of snails that jumped from the predator, increased their latency to jump and altered their escape trajectory. Elevated-CO_2 impaired decision making but did not affect physical escape ability. Antipredator behaviour was fully restored by treatment with gabazine, a GABA receptor antagonist of some invertebrate nervous systems, indicating potential interference of neurotransmitter receptor function by elevated-CO_2 in invertebrates, as previously observed in marine fishes. Altered behaviour of marine invertebrates at projected mid- to end-of-century CO_2 levels could have potentially far-reaching implications for marine ecosystems.

March 25, 16:30 (S2-9815)

Effects of elevated CO_2 on fish behaviour undiminished by transgenerational acclimation

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Behaviour and sensory performance of marine fishes are impaired at CO_2 levels projected to occur in the ocean in the next 50-100 years, and there is limited potential for within-generation acclimation to elevated CO_2. However, whether fish behaviour can acclimate or adapt to elevated CO_2 over multiple generations remains unanswered. We tested for transgenerational acclimation of reef fish olfactory preferences and behavioural lateralization at moderate (656 µatm) and high (912 µatm) end-of-century CO_2 projections. Juvenile spiny damselfish, *Acanthochromis polyacanthus*, from control parents (446 µatm) exhibited an innate avoidance to chemical alarm cue (CAC) when reared in control conditions. In contrast, juveniles lost their innate avoidance of CAC and even became strongly attracted to CAC when reared at elevated CO_2 levels. Juveniles from parents maintained at mid-CO_2 and high-CO_2 levels also lost their innate avoidance of CAC when reared in elevated CO_2, demonstrating no capacity for transgenerational acclimation of olfactory responses. Behavioural lateralization was also disrupted for juveniles reared under elevated CO_2, regardless of parental conditioning. Our results show minimal potential for transgenerational acclimation in this fish, suggesting that genetic adaptation will be necessary to overcome the effects of ocean acidification on behaviour.

S2

March 25, 16:50 (S2-10241)

Effects of ocean acidification and global warming on the physiological ecology of rhodoliths (Rhodophyta) and seagrass

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Seagrasses and free-living calcareous algae (rhodoliths or maerl) hold crucial roles in coastal marine ecosystems, representing one of the principal primary producers and serving as carbonate biofactories, respectively. As anthropogenic alterations increase across the globe, these two photosynthesizing organisms are likely to face drastic changes in their physiology, which will certainly have effects on the rest of the marine community. The seagrass, *Halodule wrightii* Ascherson, and rhodoliths, *Mesophyllum erubescens*, *Lithothamnion brasiliensis* and *Lithophyllum* sp. were exposed to elevated conditions of pCO_2 and temperature in an outdoor Mesocosm experiment where Optimum quantum yield (Fv/Fm) and Calcification rates were measured to evaluate their physiological responses. Both physiological parameters reveal the importance of the evaluation of the effect of elevated pCO_2 and temperature together, as rhodoliths responded differently to one elevated variable than they did to both together, which also varies based on the species. Seagrasses showed affinity to increased pCO_2, within the 28 day experiment, obviated by fluorescence analyses. These physiological changes are likely to cause shifts in marine community structure due to differential tolerance of photosynthetic organisms, a very important issue considering the social, economic and biodiversity importance of these ecosystems.

March 25, 17:10 (S2-10185)

The effect of ocean warming and acidification on the aerobic and anaerobic metabolic potential of fish early life stages

Marta S. **Pimentel**[1,2,3], Filipa Faleiro[1,2], Jorge Machado[3], Myron A. Peck[4], Hans Pörtner[5] and Rui Rosa[1,2]

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Until now it is not known how the activity of metabolic enzymes of fish early life stages will change with the combined effects of future ocean acidification and warming. Different lifestyles and environmental changes may be reflected in fish larvae physiology, namely in their anaerobic power. Activity levels of respiratory enzymes such as citrate synthase (CS), lactate dehydrogenase (LDH) and malate dehydrogenase (MDH) were measured in several marine fish larvae having different life-history strategies, namely *Solea senegalensis*, *Sparus aurata* and *Hippocampus reidi*. Citrate synthase, a mitochondrial enzyme indicative of aerobic metabolic potential, and the glycolytic enzyme LDH of anaerobic metabolic potential are known to be an excellent tool for the analysis of environmental variations.

We reasoned that by comparing the enzymatic activities of fish larvae with widely different life strategies and locomotory abilities (by comparing continuous swimmers such as *Sparus aurata* and *Hippocampus reidi* with more sedentary, *Solea senegalensis*) we might obtain insights into the relationship between such habits and enzymatic activity. Additionally, the results may reveal, for the first time, that future environmental conditions may impact the respiratory capacity of fish early life stages. The chronic exposure to these future conditions may compromise the fitness and survival of fish populations.

March 25, 17:30 (S2-10137)

Ocean acidification causes disorientation in fish larvae during critical settlement stage

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The dispersal of larvae and their settlement to suitable habitat is fundamental to replenishment of marine populations and communities. Sound is a critical part of this process because many larvae use it as a cue for orientation towards suitable settlement habitat. Ocean acidification has profound effects on marine life, but its effect on navigating oceanic larvae is lacking. Here we show that ocean acidification strikingly caused a switch in role of marine sound cues from attractor to repellent in the auditory preferences of fish larvae. This effect of ocean acidification puts at risk the complex process of larval orientation, settlement, and habitat connectivity.

March 25, 17:50 (S2-10131)

Ecophysiology of shark early stages under climate change

Rui **Rosa**[1,2], José R. Paula[1,2], Miguel Baptista[1,2], Vanessa M. Lopes[1,2], Katja Trübenbach[1,2], Marta S. Pimentel[1,2], Ricardo Calado[3] and Tiago Repolho[1,2]

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Sharks occupy high trophic levels in marine habitats and play a key role in the structure, function and health of marine ecosystems. Sharks are also one of the most threatened groups of marine animals worldwide, mostly due to overfishing and habitat degradation or loss. In fact, though having evolved to fill many ecological niches across a wide range of habitats, sharks have limited capability to rapidly adapt to human-induced changes in their environments. Until now, ocean acidification was not considered as a direct climate-related threat to elasmobranchs. In this study, we examined, for the first time, the effects of climate change on the early life stages of the tropical bamboo shark *Chiloscyllium punctatum*. Specifically, we analyzed the long-term (five months, encompassing embryogenesis and one month post-hatching) effects of the projected scenarios of ocean acidification (ΔpH 0.5) and warming (+4°C) for 2100 in respect to: i) specific growth and fulton condition, ii) metabolic and ventilation rates, iii) heat shock response (HSR), iv) lipid peroxidation, v) antioxidant enzymatic levels [*e.g.* superoxide dismutase (SOD), catalase (CAT) and glutathione-S-transferase (GST))]; vi) respiratory enzyme activities [*i.e.* aerobic – citrate synthase (CS), pyruvate synthase (PS), malate dehydrogenase (MDH); anaerobic - lactate dehydrogenase (LDH)]; and vii) digestive enzymatic activities (including trypsin, aminopeptidase and alkaline phosphatase). The future conditions had a negative impact on the growth, metabolism and enzymatic machinery of embryos and juveniles. The fitness reduction of these shark early life stages may compromise recruitment and survival of local populations of bamboo sharks in the tropical oceans of tomorrow.

S2

S2 Oral Presentations, Day 2 March 26
Ocean acidification

March 26, 09:00 (S2-10052), Invited

Ocean acidification along the southeastern Pacific coastal ecosystems: Biological responses, interactions with multiple stressors and human dimensions

Nelson **Lagos**[1,2], Marco Lardies[3,2], Bernardo Broitman[4,2], Stefan Gelcich[5,2], Felipe Vasquez[6,2] and Cristián Vargas[7,2]

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We review the Ocean Acidification (OA) research in Chile and nearby countries, describing the present understanding about the interaction of OA with multiple stressors in coastal areas, the biological responses to OA of key species, the vulnerability of socioeconomic sectors that rely on them, and the needs for capacity building and networking in Latin America. Differences in terms of monitoring programs in the area determine a partial understanding of the role of global stressor such as temperature, acidification and deoxygenation, and their interactions with regional or local drivers of OA (*e.g.*, freshwater inputs, eutrophication). Experimental evaluation of biological responses has been performed mostly in Chile, and over few key species of socioeconomic importance. Experimental (mesoscosm) evidence highlight that biomass production in the mussels farming developed in northern Patagonia (Chile) could be reduced in almost 30% only due to increased CO_2 in seawater. The area is a net sink for CO_2, suggesting vulnerability for this aquaculture sector, which is dependent on the natural production of seeds and the health of the waters where the cultivation is performed. Similarities in terms of the structure and functioning in costal upwelling ecosystems suggest that similar results may be projected for areas off Peru and benthic resources therein. Upwelling ecosystems are the most productive of the planet, but is projected that will suffer a rapid and progressive acidification in the incoming decades, thus threatening the ecosystems services provided to our society.

March 26, 09:30 (S2-10056)

Simulated anthropogenic CO_2 storage and acidification of the Mediterranean Sea

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Constraints on the Mediterranean Sea's storage of anthropogenic CO_2 are limited, coming only from data-based approaches that disagree by more than a factor of two. Here we simulate this marginal sea's anthropogenic carbon storage by applying a perturbation approach in a high-resolution regional model. Our model simulates that between 1800 and 2001, basin-wide CO_2 storage by the Mediterranean Sea has increased by 1.0 Pg C, a lower limit based on the corresponding model evaluation with CFC-12, indicating inadequate simulated deep-water ventilation. Furthermore, by testing a data-based approach (Transit Time Distribution) in our model, comparing simulated anthropogenic CO_2 to values computed from simulated CFC-12 and physical variables, we conclude that the associated basin-wide storage of 1.7 Pg, published previously, must be an upper bound. Out of the total simulated storage of 1.0 Pg C, 75% comes from air-sea exchange into the Mediterranean Sea and 25% comes from net transport from the Atlantic across the Strait of Gibraltar. Sensitivity tests indicate that the Mediterranean Sea's higher total alkalinity, relative to the global-ocean mean, enhances the Mediterranean's total inventory of anthropogenic carbon by 10%. Yet the corresponding average anthropogenic change in surface pH does not differ significantly from the global-ocean average, despite higher total alkalinity. In Mediterranean deep waters, the pH change is estimated to be between −0.005 and −0.06 pH units.

March 26, 09:50 (S2-10223)

A 200-year record of interannual pH and SST variability from the Lesser Antilles (Caribbean Sea) inferred from a *Siderastrea siderea* reef coral

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Ocean acidification and global warming caused by the rising levels of anthropogenic CO_2 in the atmosphere need to be better constrained by long-term studies of high resolution natural archives, especially at inter-annual and decadal scales. In the framework of the French INSU program LEFE/CYBER ACID-Antilles, we developed a 200 year long interannual time series of sea surface pH and temperature based on the geochemical composition of tropical reef forming coral. The selected tropical coral called CHANCEL-1 is a colony of genus *Siderastrea siderea* which was collected in 2008 from a living micro–atoll off Martinique in the Lesser Antilles, facing the eastern side of the Caribbean Sea. The colony of 1-meter extension presents a mean growth rate of 4 – 5 mm/yr. Along the growth axis, we measured the boron isotopic composition (^{11}B) and trace element ratios (Li/Mg, Sr/Ca), which reveal a progressive decrease of the surface water pH and increase of temperature during the past 200 years respectively. These observations cooperate the anthropogenic forcing, *i.e.* rising atmospheric CO_2 and rising sea surface temperatures due to global warming. However, other processes apparently affect the geochemical records, as indicated by sub-decadal variations of pH and temperature reconstruction overprinting the long term global trend. Possible drivers of such most likely regional variability might be decadal changes of oceanographic conditions (upwelling, freshwater runoff, seawater masse changes, *etc.*) as well as species dependent biological controls.

March 26, 10:10 (S2-10122)

Climate change impacts on tropical and temperate photosynthetic sea slugs

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As a consequence of increasing anthropogenic CO_2 emissions, oceans are becoming more acidic and warmer. Here we evaluated the impact of environmental hypercapnia (ΔpH = 0.5 units) and warming (+4°C) expected by the end of this century on survival, growth, fertility, heat shock response and antioxidant defense mechanisms of two photosynthetic sea slugs, the temperate *Elysia viridis* and the tropical *E. clark*i. Although possessing physiological mechanisms against environmental stress (ability to increase antioxidant activity and reduce ROS accumulation), our results demonstrated that temperate and tropical photosynthetic sea slugs are vulnerable to warming and acidification. More specifically, survival and growth were negatively impacted by these climate change–related variables. In opposition to the temperate species, chloroplast's bleaching was observed for the tropical sea slug and the maximum quantum yield of kleptoplast photosystem II (Fv/Fm) was not preserved, which indicate that photosymbiosis in the tropics will be more affected by the future environmental conditions.

March 26, 11:00 (S2-9892)

The other ocean acidification problem: CO_2 as a resource among competitors for ecosystem dominance

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The indirect effects of CO_2 on biogenic habitats may substantially greater roles than current thinking allows. The benefits of CO_2 vary among competing species, leaving key species (*e.g.* kelp forests) as ecological subordinates in a high CO_2 world. I present a model where future atmospheric [CO_2] acts not as a resource for kelp, but as a resource for normally subordinate mat-forming algae; a diverse and widespread group known to reduce the resilience of kelp forests and coral reefs. This hypothesis was tested by combining laboratory, large outdoor mesocosm, field CO_2 (FOCE) experiments and observations from 'natural' volcanic CO_2 vents.

March 26, 11:20 (S2-10033)

Who are the most vulnerable? – A global assessment of exposure, sensitivity, adaptive capacity and vulnerability to ocean acidification

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Laboratory studies have demonstrated that many commercial shellfish species (molluscs and crustaceans) are sensitive to the impacts of ocean acidification. In this contribution we present a country-by-country analysis aimed at determining which nations could be most vulnerable in the future on the basis of their present reliance on shellfish resources, their exposure to modification of pH and their ability to adapt.

In terms of shellfish production (fisheries and aquaculture) China and USA are the most important countries in absolute terms, although per capita consumption of shellfish is highest in Iceland and Hong Kong. As a percentage of total protein intake, shellfish are most important in Iceland, Guyana and Suriname. These factors are taken into account in the 'Sensitivity' measure (S).

IPCC model outputs suggest the largest projected decrease in surface pH will occur in warmer, low and mid-latitudes, however it is high latitudes (particularly the Arctic) and upwelling regions that will become under-saturated first with respect to aragonite. These factors are taken into account in the 'Exposure' measure (E).

'Vulnerability' (V) is a function of 'Exposure', 'Sensitivity' and 'Adaptive Capacity' (AC), the latter based on national GDP and development indicators.

The countries highlighted as most vulnerable in this analysis are very different to those highlighted in previous assessments based on changes in seawater temperature. This analysis also considers reliance of countries on fishery resources obtained from within coral reefs, where fin-fish rely on corals for protection and habitat, but corals are also known to be highly vulnerable to ocean acidification.

March 26, 11:40 (S2-9895)

Ocean acidification, warming and the biological carbon pump

Uta **Passow**

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Aggregation, which terminates diatom blooms, contributes appreciably to the sinking and subsequent sequestration of carbon via the biological carbon pump. Warming and ocean acidification may impact the functioning of the biological carbon pump in a variety of ways. Results from a series of experiments investigating consequence of ocean acidification and warming on carbon utilization and partitioning, as well as on aggregation and sinking will be highlighted. The influence of pCO_2 on growth rate, TEP production and carbon partitioning depends on species and on the specific growth conditions, *e.g.* irradiance, temperature and nutrient availability. In contrast to expectations, increased TEP concentrations under future pCO_2 conditions do not necessarily result in increased aggregation rates. Size specific sinking velocity of aggregates decreased at elevated temperature and higher pCO_2. These results challenge the hypothesis that elevated temperature and ocean acidification as expected in the future ocean will result in increased carbon flux and thus in a negative feed-back to global change. Results also provide an example that established relationships, like that between TEP concentration, aggregation and flux, may not extend to future conditions.

March 26, 12:00 (S2-10229)

Climate change in the shallows – interacting effects of diel-cycling hypoxia and acidification

Denise **Breitburg**, Andrew Keppel, Seth Miller and Rebecca Burrell

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Shallow estuarine and coastal waters are nursery grounds for juveniles of economically important finfish, and primary habitat for shellfish and forage fish species. Both oxygen and pH in these habitats can undergo extreme variations on daily or tidal cycles. These cycles are exacerbated by anthropogenic nutrient loads, and their severity and effects are predicted to worsen as increasing atmospheric CO_2 increases acidity, and as rising temperatures decrease oxygen solubility and increase metabolic requirements. We are examining effects of diel-cycling hypoxia and diel-cycling acidification on juvenile oysters and fishes in Chesapeake Bay utilizing field comparisons and a laboratory system that creates daily cycles of oxygen and pH. Exposure to low pH increased sensitivity of inland and Atlantic silversides (*Menidia beryllina and M. menidia*) to hypoxia. Fish exposed to both stressors utilized aquatic surface respiration and died at higher oxygen concentrations than fish exposed to only low oxygen. Fish from the site with frequent low oxygen and pH were less sensitive to these stressors than fish from a site with better water quality, indicating the potential for small-scale local adaptation or acclimation. The greatest growth reductions of oysters (*Crassostrea virginica*) caused by diel-cycling pH occurred when oxygen remained high rather than when oxygen cycled between severe hypoxia and supersaturation. Our results indicate that oxygen*pH interactions vary, postlarval estuarine fish and shellfish are sensitive to pH, and, in spite of some potential for local adaptation, these kinds of species are likely to be negatively affected as acidification worsens.

March 26, 12:20 (S2-10160)

Giant clams and rising CO_2: Light may ameliorate effects of ocean acidification in a solar-powered animal

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Global climate change and ocean acidification pose a serious threat to marine life. Marine invertebrates are particularly susceptible to ocean acidification, especially highly calcareous taxa such as molluscs, echinoderms and corals. The largest of all bivalve molluscs, giant clams, are already threatened by a variety of local pressures, including overharvesting, and are in decline worldwide. Giant clams are listed as 'vulnerable' on the IUCN Red List of Threatened Species, but now climate change and ocean acidification pose additional threats to their conservation. Unlike most molluscs, however, giant clams are 'solar-powered' animals containing photosynthetic autotrophic symbionts suggesting that light could influence the effects of ocean acidification on these vulnerable animals. In this study, juvenile fluted giant clams *Tridacna squamosa* were exposed to three levels of carbon dioxide (CO_2) (control ~400, mid ~650 and high ~950 µatm) and light (photosynthetically active radiation 35, 65 and 304 µmol photons m^{-2} s^{-1}). Elevated CO_2 projected for the end of this century (~650 and ~950 µatm) reduced giant clam survival and growth at mid-light levels. However, effects of CO_2 on survival were absent at high-light, with 100 % survival across all CO_2 levels. Effects of CO_2 on growth of surviving clams were lessened, but not removed, at high-light levels. Shell growth and total animal mass gain were still reduced at high-CO_2. This study demonstrates the potential for light to alleviate effects of ocean acidification on survival and growth in a threatened calcareous marine invertebrate, providing potential opportunities for management intervention.

S3 Oral Presentations March 27
Changing ocean chemistry: From trace elements and isotopes to radiochemistry and organic chemicals of environmental concern

March 27, 11:20 (S3-10030), Invited

The role of the Southern Ocean export in the biogeochemical cycling of zinc, cadmium and cobalt in the Atlantic Ocean

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Zinc is an essential marine micronutrient utilised by phytoplankton in enzymes such as carbonic anhydrase and alkaline phosphate. Throughout the ocean, zinc displays nutrient like profiles similar to silicate. However, zinc is co-located with phosphate in phytoplankton and regenerated with phosphate in the upper ocean, not in the deep with silicate. Here we present data on high resolution Zn distributions in the Atlantic Ocean from the GEOTRACES program and the use a new tracer Zn* to examine what drives the global cycling of zinc in the oceans. Our data indicate preferential removal of zinc by phytoplankton in the Southern Ocean, resulting in low zinc concentrations in SAMW that are transported to Atlantic Ocean, This has implications for low Zn:P in surface waters of the sub-tropical Atlantic. Zinc isotopic data reveal that the global deep ocean is isotopically homogeneous and suggests that Zn is largely sourced from the Southern Ocean. As the marine biogeochemistry of cobalt and cadmium are inter-related through biochemical co-substitution in carbonic anhydrase, understanding the rates and mechanism by which these bioactive trace metals are advected from the Southern Ocean to the photic zone is critical for oceanic primary productivity. Both cadmium and cobalt are also depleted in SAMW but to differing degrees, which drives nutrient stoichiometries in the Atlantic Ocean.

March 27, 11:50 (S3-10204)

Study of the sources of iron to the southern Brazilian coast and adjacent ocean

Leonardo **Contreira-Pereira**, Carlos F.F. de Andrade, Karina Attisano, Kayla Lima, Mariele Paiva, Gabriel Karagiannis, Cátia Von-Ahn, Daniel Costa and Luis Felipe Hax Niencheski

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The oceanic region adjacent to the southern Brazilian coast, where lies the Brazil - Malvinas confluence zone, is an important area of primary production with intense fishing activity. The main sources and processes controlling macro and micronutrients are, however, insufficiently known. On the last decade, our lab has extensively worked on the study of the submarine groundwater discharge along this coast. We have shown that SGD is an important source of iron (Windom *et al.*, 2006) and nutrients (Niencheski *et al.*, 2007) to this area. In order to investigate the scale and seasonal variability of trace metals input to the adjacent ocean, as well as the biogeochemical processes involved, we have programmed a series of cruises on board of the N/Pq Atlântico Sul (FURG), under the National Institute of Science and Technology - Integrated Oceanography and Multiple Uses of the Continental Shelf and Adjacent Ocean (INCT Mar –COI) program. At the moment we have performed two cruises (1/13 and 7/14) with a number of transects perpendicular to the coast, up to 100 km offshore. First results will be presented as well as an insight on the assessment of the extent of SGD as an iron source for this oceanic region. A perspective for trace metal research on this area, based on the new infra-sctructure of the INCT Mar-COI for the next scheduled cruises will be also presented.

March 27, 12:10 (S3-10065)

Potential changes in iron availability through long-term changes in zooplankton

Sarah L.C. **Giering**[1], Sebastian Steigenberger[2], Eric P. Achterberg[3], Richard Sanders[2] and Daniel J. Mayor[1]

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Low dissolved iron (DFe) concentrations limit primary production in most high-nutrient low-chlorophyll regions. Increased recycling of iron (Fe) relative to nitrogen (N) by zooplankton may help to sustain phytoplankton production in these conditions. We concurrently determined rates of DFe and ammonium (NH_4^+) recycling by natural mesozooplankton communities in high-nutrient low-chlorophyll conditions of the Irminger Basin, Northeast Atlantic. NH_4^+ excretion remained constant and ranged between 14.2–54.1 nmol NH_4^+ mg dry weight^{-1} h^{-1}. Fe recycling ranged between 6–138 pmol DFe mg dry weight^{-1} h^{-1}during the first hour and decreased thereafter, reflecting the transition from the loss of phytoplankton-derived Fe to basal DFe excretion. Mesozooplankton-driven nutrient recycling was estimated to support 6–59% and <1–13% of the respective phytoplankton requirements for DFe and N in 2010; DFe:N regeneration ratios were 5–26 times larger than those required by phytoplankton. We subsequently use these data to illustrate the potential effects of changes in the abundance and distribution of zooplankton, known responses to climate change, on ocean chemistry. Coupled to historic abundance data of mesozooplankton in the Irminger Basin from 1958-2007, our observed DFe release rates suggest that iron recycling has increased in the eastern Irminger Basin, whereas it stayed constant in the western Irminger Basin. Our study highlights the need to consider how climate change effects on zooplankton populations will influence the biogeochemical functioning of marine ecosystems.

March 27, 14:00 (S3-10014)

High variability of dissolved iron concentrations in the vicinity of the Kerguelen Island (Southern Ocean)

Géraldine **Sarthou**[1], Fabien Quéroué[1,2,3,4], Fanny Chever[1], Pier van der Merwe[4], Delphine Lannuzel[3,4], Ashley T. Townsend[5], Eva Bucciarelli[1,2], Hélène F. Planquette[1], Marie Cheize[1], Stéphane Blain[6,7], Francesco d'Ovidio[8] and Andy R. Bowie[3,4]

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Dissolved Fe (dFe) was measured in the upper 1300 m of the water column in the vicinity of Kerguelen Island as part of the second KErguelen Ocean Plateau compared Study (KEOPS2). Concentrations ranged from 0.06 nmol L-1 in offshore, Southern Ocean waters, to 3.82 nmol L-1 within Hillsborough Bay, on the northeastern coast of Kerguelen Island. Direct island runoff, glacial melting and resuspended sediments were identified as important inputs of dFe that could potentially fertilize the northern part of the plateau. A significant deep dFe enrichment was observed over the plateau with dFe concentrations increasing up to 1.30 nmol L-1 close to the seafloor, probably due to sediment resuspension and associated pore water release. Biological uptake was identified as a likely explanation for the decrease in dFe concentrations between two visits (28 days apart) at a station above the plateau. Our results allowed studying other processes and sources, such as atmospheric inputs, lateral advection of enriched seawater, remineralisation processes and the influence of the Polar Front (PF) as a vector for Fe transport. Overall, heterogeneous sources of Fe over and off the Kerguelen Plateau, in addition to strong variability in Fe supply by vertical or horizontal transport, may explain the high variability in dFe concentrations observed during this study.

March 27, 14:20 (S3-9933)

Temporal and spatial gradients of anthropogenic Gd in San Francisco Bay

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The use of refractory gadolinium (Gd) complexes as contrast agents in magnetic resonance imaging (MRI) has resulted in point source discharges of anthropogenic Gd into the environment. We evaluated the potential impact of those discharges by investigating temporal and spatial variations of Gd and other rare earth elements (REE) in surface waters collected in transects of San Francisco Bay (SFB) over two decades (1993-2013). The REE were pre-concentrated from the water with an off-line procedure, using the NOBIAS-chelate PA-1® resin, prior to analysis by high resolution inductively coupled plasma mass spectrometry (HR ICP-MS). The REE data from SFB were then normalized to those of the GEOTRACES Surface Coastal (GSC) reference sample, collected in the Santa Barbara Basin off Southern California. Those normalized REE measurements revealed a temporal increase in the Gd anomaly from the early 1990s to the present. The anomaly was highest in the southern reach of SFB, which is surrounded by several large hospitals and research centers that use Gd, and it was ~ 50-fold higher than in the GSC in Southern California coastal waters. There was also a spatial gradient in the anomaly within SFB, with values decreasing in a northerly direction within SFB. Consequently, these measurements support concerns that REEs, formerly 'exotic' trace elements in high-tech applications, have now become emerging contaminants and may also be used as tracers of wastewater components in the marine environment.

March 27, 14:40 (S3-10155)

Historical trends in hypoxia of the southeastern Gulf of California: 18,000 year record within Pescadero Basin sediments

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We present the first high-resolution multiproxy reconstruction of the past 18,000 years of oceanic redox variability in the southeastern Gulf of California (GC) and eastern Pacific. Fluctuations of oxygen levels are a crucial regulator responsible for changes in biota distribution, water chemistry, physicochemical transformations of dissolved and particulate phases for trace elements in the water column, and formation of authigenic minerals, among other effects. A gravity core from Pescadero Basin, located within the oxygen minimum zone (OMZ) of the southern GC, was thoroughly studied in terms of C, S, redox sensitive trace elements (considering the non-lithogenic fractions), Fe chemistry (Fe_{HR}/Fe_T ratio). Two clear episodes of peleoceanographic variability were revealed, associated with changes in hypoxia. The first period (18.0 - 11.6 cal kyr BP), represented by massive sediments, points to a time with an oxygenated water column and moderate productivity, elucidated by low C_{org}, high S and a relatively low redox sensitive trace element content (Mo and U). The second (11.6 cal kyr BP - present), with a clear lamination pattern, indicates a suboxic/anoxic episode, evidenced by higher C_{org}, Mo and U. Most of the mentioned redox-proxies and preliminary isotopic data point to the sea-level shift that immediately followed the Last Glacial Maximum and transitioned Pescadero hydrochemistry from a shallow well-ventilated basin (prior to 11.6 cal kyr BP) to a deep OMZ system. Differences and similarities with other marine sedimentary records, such as Cariaco, Guaymas and Alfonso basins, will be discussed in the context of Younger Dryas and Bølling-Allerød climatic conditions.

March 27, 15:00 (S3-9862)

Stable isotopic records of otoliths and clam shells in detecting the climate change and the effects of ocean acidification

Yongwen **Gao**

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The use of stable carbon and oxygen isotope ratio ($^{13}C/^{12}C$ or ^{13}C, and $^{18}O/^{16}O$ or ^{18}O) analyses in otoliths and clam shells has received growing attention in recent years, particularly in examining the climate-related regime shifts and the effects of ocean acidification. As the anthropogenic CO_2 sinks into ocean, it will produce HCO_3^- and CO_3^{2-} and then affect the carbonate saturation state (Ω). The process can be detected from carbon sources and the isotopic fractionation of ^{13}C between blood DIC (dissolved inorganic carbon) and the carbonate proxies. Here we report examples of stable isotope investigations on Pacific halibut (*Hippoglossus stenolepis*) otoliths and Pacific geoduck (*Panopea abrupta*) shells. In general, the ^{18}O values of Pacific halibut otoliths ranged from -1.5 to +2.8‰, whereas the ^{13}C values of the same otoliths ranged from -3.3 to +0.9 ‰. Evaluation of the isotopic composition of mature halibut (ages 8-12) indicated that the 1990 regime shift may affect the Pacific halibut stocks, with a temperature decrease of about 2 °C. The ^{18}O values of geoduck shells ranged from –1.34 to +0.95‰, while the ^{13}C values of the same samples ranged from –2.19 to +0.35‰. There were significant isotopic differences between shell collection sites, and the decrease of ^{13}C was consistent with the pH and dissolved oxygen variations. Thus we concluded that stable isotopic records of carbonate (otoliths and shells) are potentially useful in detecting the decadal-scale (*e.g.*, the last 20-30 years) climate changes and the effects of ocean acidification.

March 27, 15:20 (S3-10064)

Interactions of persistent organic pollutants with marine phytoplankton in temperate and polar seawaters

Pedro **Echeveste**[1], Cristóbal Galbán-Malagón[2], Jordi Dachs[3] and Susana Agustí[4]

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Persistent organic pollutants (POPs) undergo long-range atmospheric transport before being deposited to the global oceans, where they partition to organic matter, incorporating into marine phytoplankton and consequently to marine food chain. These organisms trap POPs and retard their transport to cold waters by enhanced air–water diffusive fluxes and organic carbon settling fluxes (biological pump). The goal of this study was to analyze the factors influencing these air-water fluxes and to determine the effects of naturally occurring complex mixtures of organic pollutants in temperate and polar phytoplankton communities of the Mediterranean Sea and the Southern Ocean, respectively. Atmospheric and dissolved concentrations of POPs were one order of magnitude higher in the Mediterranean Sea than in the Southern Ocean, presenting higher concentrations both in air and seawater, with the air-to-water fluxes increasing the amount of POPs reaching phytoplankton. Productivity in the Mediterranean was also higher than that in the Southern Ocean. Thus, when the effects of complex mixtures of POPs were tested, almost all the phytoplankton groups were significantly affected by POPs, with effects manifesting when concentrations were tenfold the field levels. Moreover, results pointed to recurrent pollution as an evolutionary driver of tolerance to pollutant stress.

S4 Oral Presentations March 23
Regional models for predictions of climate change impacts: Methods, uncertainties and challenges

March 23, 14:00 (S4-10013), Invited

Regional models for projections of climate change impacts on small pelagic fishes in the western North Pacific

Shin-ichi **Ito**[1], Takeshi Okunishi[2], Taketo Hashioka[3], Takashi T. Sakamoto[1], Naoki Yoshie[4], Kosei Komatsu[1] and Akinori Takasuka[5]

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Western North Pacific is one of the most productive areas for small pelagic fishes in the world and responses of the small pelagic fishes to climate change constitute an important issue related to the future world food security. Several types of multi-trophic level ecosystem models have been developed by coupling physical, biogeochemical–plankton and fish models to project the responses of the small pelagic fishes to climate change. In this presentation, we will introduce two examples: Japanese sardine and Pacific saury. Both examples used future climate condition extracted from high-resolution climate model as forcing. For Japanese sardine, the physical fields derived from the climate model were used to force a regional lower-trophic-level ecosystem model and fish migration-growth model. For Pacific saury, the physical fields derived from the climate model were used to force a finer-resolution regional physical and lower-trophic-level ecosystem coupled model and a fish migration–growth model. The model results demonstrated possible impacts of climate change on the growth and migration patterns of these small pelagic species. Based on the two examples and plus new observational findings of a key area which is important in terms of atmospheric storm activity, ocean water mass formation, and marine biological production, we will address the challenges of studying climate change impacts on small pelagic fishes using regional model projections.

March 23, 14:30 (S4-9977)

Trophic amplification of ocean productivity trends in a changing climate

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Pronounced projected 21st century trends in regional oceanic net primary production (NPP) raise the prospect of significant redistributions of marine resources. Recent results further suggest that NPP changes may be amplified at higher trophic levels. Here, we elucidate the role of planktonic food web dynamics in driving projected changes in mesozooplankton production (MESOZP) found to be approximately twice as large as projected changes in NPP by the latter half of the 21st century in the GFDL's ESM2M-COBALT Earth System Model. Globally, MESOZP declined by 7.9% but regional MESOZP changes sometimes exceeded 50%. Changes in three planktonic food web properties - zooplankton growth efficiency (ZGE), the trophic level of mesozooplankton (MESOTL), and the fraction of NPP consumed by zooplankton (zooplankton-phytoplankton coupling, ZPC), explain the amplification. ZGE changed with NPP, amplifying both NPP increases and decreases. Negative amplification (*i.e.*, exacerbation) of projected subtropical NPP declines via this mechanism was particularly strong since consumers in the subtropics have limited surplus energy above basal metabolic costs. Increased MESOTL resulted from sharp projected declines in large phytoplankton production with increased stratification. Marked ZPC increases were projected for high latitude regions experiencing shoaling of deep winter mixing or decreased winter sea ice, both tending to increase winter zooplankton biomass and grazer control of spring blooms. Improved understanding of the diverse factors governing ZGE, MESOTL and ZPC could refine projections of future fisheries yields.

March 23, 14:50 (S4-9805)

Downscaling the 1990-2100 ocean climate projections for the Arabian Gulf

Edson J.R. **Pereira** and Ilana Wainer

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In this study the results of the Arabian Sea downscaling of IPCC related climate change scenario results (AR5 - RCP 8.5) using a complex regional model (ROMS) are presented. We show the model skill needed to keep on track the anthropogenic trends and variabilities derived from the climate projected global scenario and its high-resolution local impacts along the 21th century. Because of the area's "intermediate water mass" formation characteristics the analysis presented here focuses on the seasonal variability of salinity and its transport out of the Arabian Gulf system. The centennial increase of the specific humidity amplitude signal is also evaluated, since it is the main atmospheric signal that contributes to fresh water balance, considering that the area is extremely dry - low precipitation and runoff range. The negative fresh water fluxes induced by anthropogenic sources are not considered in this long term simulation, although it could provide the baseline for the understanding of the importance and physical implications for the future dynamics in the area.

March 23, 15:10 (S4-10087)

A regional biogeochemical climate model for the British Columbia continental shelf

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The British Columbia shelf is at the northern end of the California Current System and is influenced by summer coastal upwelling, mesoscale eddies, and freshwater inputs. A regional ocean-only coupled circulation-biogeochemical (ROMS) model of this region has been developed to gain a better understanding of the potential impact of climate variability and change on lower trophic levels and the biogeochemistry of the region. A first step to address the impacts of climate variability on marine ecosystem is to develop biophysical models that simulate the present ecosystem state in relation to the climate record and can be used to examine the influence of different forcing acting, at different scales, on ecological processes. This allows us to evaluate the role of specific mechanisms in governing the observed and future variability of the physical-biological environment. This talk will present results from a coupled plankton / circulation (ROMS) model of the British Columbia continental shelf used to simulate present and future conditions. In particular, we will focus on the capability of the model to reproduce observations and to respond to main episodic events (seasonal cycle and El Niño events) as well as preliminary results from simulated future conditions. The later include warmer and fresher waters, stronger winter winds, but little change to the summer winds and contemporary upwelling conditions.

March 23, 16:00 (S4-10206)

Reviewing the use of computer-based modelling to study squid larval dispersal: Experiences from South Africa and Brazil

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The study of larval dispersal to clarify marine ecologic and fishery-related key questions, such as metapopulation connectivity and recruitment, has becoming increasingly important. Because of inherent difficulties of plankton sampling, and the often prohibitive costs of in situ studies, computer-based modelling tools have been developed and applied to a number of ecological/fishery problems. Among these, coupling of particle-tracking Lagrangian Individual-Based Models to 3D circulation models through computational tools has becoming very popular. From the latter, the ICHTHYOP® software has been intensively employed, and there are currently some 55 papers published using this tool. Whereas much of the pioneer and recent efforts using ICHTHYOP were directed to ichthyoplankton, comparatively much less attention was given to early life stages of invertebrates. Among the few invertebrate examples published, only three studies account for squids: two in South Africa (for the chokka squid – *Loligo reynaudii*) and one in Brazil (for the tropical arrow squid – *Doryteuthis plei*). This review aims to

compare studies between the two squid species as well as between these and other taxa. Relevant factors discussed here include geographic areas and oceanographic regimes, circulation model types, circulation model grid sizes, information on the squid spawning sites and behavior, and biological aspects of squid paralarvae biology, ecology and behavior of relevance for modelling larval dispersal. It is expected to provide a comprehensive review on published data as well as identify research gaps as a step forward better and refined future studies, including implications of climate change on the model's outputs.

March 23, 16:20 (S4-9886)

Comparison numerical models results and hydrographic data in the Atlantic Ocean

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The main goal of this work is to determine the Atlantic Ocean water mass variability according to data of hydrographical sections at 60°N, 24°N, 8°S 30°S , meridional section across the Atlantic and the results of numerical models of ocean circulation (models SODA, ECCO, Nemovar and *etc.*). The results of some numerical models allow us to average over the decades, years and months, and calculate transport for the zonal sections. We estimate water masses transport and total mass and heat fluxes for these sections and key areas (for Gulf stream, in the Denmark and Gibraltar Straits and *etc.*), and assess the intensity of the Meridional overturning circulation. The variability of heat storage of the Atlantic is also estimated. These calculations are compared with those obtained during the measurements at hydrographic sections, where the differences are determined and analyzed. According to the model to estimate how the section duration time influences water mass characteristics and transport.

March 23, 16:40 (S4-10028)

Marine climate projections for the NW European shelf seas: Dynamically downscaling a perturbed physics ensemble to explore climate uncertainty and temporal response

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The North-West European (NWE) shelf seas are of considerable economic, environmental and cultural importance, and are protected by national and European evidence-based policy. Such policies often explicitly include climate change, and so require marine climate projections. There are, however, a number of scientific and technical issues that lead to uncertainty in such projections.

We have developed a system to provide an ensemble of transient climate projections that quantify one important aspect of climate uncertainty - associated with the choice of (often poorly constrained) global climate model parameters. We have used model output from a coupled Atmosphere-Ocean General Circulation Model (HadCM3), and consistent atmosphere-only Regional Climate Model (HadRM3), to drive a shelf seas model (POLCOM). This approach as been used to downscale a Perturbed Physics Ensemble of HadCM3 to give 11 ensemble members, each run from 1952-2098, under a single (A1B) emission scenario.

Here we present the temporal response of the physical properties of the NWE shelf seas to the climate change. Temperature and stratification shows a near-linear increase, and ensemble divergence with time, which contrasts with the more complex salinity evolution. We also consider the variance, and uncertainty, associated with the projections, which we separate into a number of categories. The balance of these categories changes with parameter, through time and across the domain.

This ensemble will be further analysed to explore climate signal emergence, and its implication for near-future climate projections. Future work will investigate other sources of uncertainty, as well as the response of the NWE shelf ecosystem.

March 23, 17:00 (S4-10238)

Fish movement and distribution drivers in a climate to fisheries model for the Bering Sea

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We use results of multi-year simulations of an end-to-end model including oceanography, lower trophic levels, fish dynamics and fisheries (FEAST model), and compare them to survey data to evaluate fish movement, distribution, and responses to environmental conditions. In particular, we focus on results for walleye pollock, Pacific cod and Arrowtooth flounder. Fish move following gradients based on potential growth (in weight) and least predation mortality (numbers of fish), with distributions differing by age and season depending on their diet, prey availability and vulnerability as prey. Temperature limitation is intrinsic to the underlying bioenergetics regulating fish growth. The model closely reproduces the extent of the cold pool in the Eastern Bering Sea shelf (waters less than 2ºC), a feature shown to influence the latitudinal and longitudinal distribution of walleye pollock and Arrowtooth flounder. Our results show fish responding to the extent of the cold pool (warm and cold conditions), and showing a distribution pattern similar to that from the survey, but differing in the marginal distribution and or center of distribution. We focus on the sources of error, and potential factors causing the discrepancies, such as distribution of prey fields, feedback to the lower trophic levels, and the number of fish removed by fisheries. Challenges going forward include refining the underlying seasonal dynamics of zooplankton and prey preferences in diets, but most importantly –improving recruitment and implementing a fleet dynamics model to forecast the distribution fishing effort.

March 23, 17:20 (S4-9908)

ROMS hindcast experiments on BOB's extreme events with daily forcing input

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Bay of Bengal (BOB) is known for its uniqueness due to being severely influenced by huge river discharges and severe monsoon time wind and precipitations. These factors not only create internal thermodynamic variability but the basin's circulations patterns are also severely influenced by these forcing factors. The seasonal and inter annual features in BOB have been studied previously by various numerical modelling studies, although those were primarily based on monthly scale and the model resolutions were also poor. So to investigate at finer temporal scale, Regional Ocean Modeling System (ROMS) has been set up for BOB and the model has been run for six years with climatological forcing until it reaches the stability period and gains proper kinetic energy. On this spin up data, daily forcing data like wind components, precipitation, fluxes have been used to simulate various case studies like some of the tropical cyclone cases and periodical events like Indian Ocean dipole. Moreover, the initial synoptic temperature and salinity conditions have been created by objective analysis technique to make model output more realistic. It is found that during cyclone cases normal circulation patterns are severely disrupted and currents start moving outward from the cyclone centre. Moreover, severe mixing makes surface temperature quite low than surrounding area. Several other hindcast experiments also have shown the ROMS is extremely sensitive towards variations in precipitation and wind data and the effects are prominent in surface salinity and temperature patterns.

March 23, 17:40 (S4-10037)

Wind wave regime of eastern European seas

Fedor N. **Gippius**[1], Alisa Yu. Medvedeva[1], Elena A. Malyarenko[1], Victor S. Arkhipkin[1], Stanislav A. Myslenkov[1] and Galina V. Surkova[2]

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The object of this study is the wind wave regime of the Baltic, Black and Caspian seas. Parameters of wind waves were calculated by mean of the third-generation wind wave model SWAN; wind speed and direction were derived from the NCEP/NCAR reanalysis for the period from 1949 to 2010. The computations were carried out continuously for every year on rectangular grids with a spatial resolution of 5 km. The timestep of the computation was 30 minutes. Values of significant wave height, wave length and period, swell height and wave energy transport were calculated.

The results of these computations are fields of seasonal average and maximal wave parameters. Areas with highest waves in the Baltic Sea are located in its central part, in the southwestern and northeastern parts in the Black Sea and in the central and southern parts of the Caspian Sea. Wave heights possible once in 100 years were assessed by the Initial Distribution Method. The interannual variability of storms was estimated. Thus, its trend increases in the Baltic Sea, remains stable in the Black Sea and decreases in the Caspian Sea.

S6 Oral Presentations March 23
Climate change in the seasonal domain: Impacts on the phenology of marine ecosystems and their consequences

March 23, 14:00 (S6-10019), Invited

Timing is everything? – Climate control on the North Pacific ecosystem phenology

Sanae **Chiba**[1], Mitsuhiro Toratani[2], Sayaka Yasunaka[3], Taketo Hashioka[1], Sonia Batten[4] and Hiroya Sugisaki[5]

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This presentation is first to summarize the phenological changes of the lower to higher trophic levels over the North Pacific. Long-term monitoring studies have revealed the changes of the lower trophic level seasonality, *e.g.* timings of spring bloom and zooplankton development, were induced by the interannual to interdecadal cool-warm cycles, which are closely related to the ENSO and Pacific Decadal Oscillation. Although it is often difficult with the data of a coarse temporal resolution to detect the consequences of the lower trophic level phenology on the higher trophic level productivity, nitrogen stable isotope (15N) of zooplankton and fish could be a useful clue to link plankton and fish. In the western North Pacific, decadal variation of 15N in *Neocalanus* copepods and pink salmon indicated that early spring bloom in the 1990s was a "good-match" for production of the copepods and salmon. Also in this talk, we will introduce the study for the project, NEOPS (New Ocean Paradigm for its biogeochemistry, ecosystem, and Sustainable use), through which we are developing the new ocean provinces in the North Pacific based on the seasonality of biogeochemical properties and phytoplankton. We aim to define the provinces with the "dynamic" rather than "static" boundaries. The preliminary province map clearly identifies the areas with a high interannual variation in the boundary locations, indicating that the biogeochemical and plankton seasonality are susceptible to climatic control in those areas. The new province would be useful *e.g.* to propose the marine protection areas in the context of phenology.

March 23, 14:30 (S6-9924)

Velocity and seasonal shift in climate: Ecologically relevant indices for predicting changes in species distributions and phenology

Michael T. **Burrows**[1], Jorge García Molinos[1], Benjamin S. Halpern[2], Anthony J. Richardson[3], Pippa Moore[4], Elvira Poloczanska[3] and David S. Schoeman[5]

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Physical changes in the world's oceans are influencing marine ecosystems in many ways, but the simplest effects are those due to shifts in location and seasonal timing of climatic conditions. Distributions of marine species are most often limited by the location of their maximum and minimum tolerated temperatures, while many seasonal events are triggered by seasonal temperature changes. Expressing changes in the physical environment in ecologically relevant ways adds predictive or comparative value. The 'velocity of climate change' gives the rate and direction of movement of isotherms across the marine seascape (km/decade). Observed shifts in species distribution correlate well for some taxa with predictions from the velocity of climate over the same periods for those localities, suggesting that this simple quantity has considerable predictive value. A second metric is the 'seasonal climate shift', giving the change in timing of changes in seasonal temperatures and potentially useful for predicting how timing of seasonal events such as reproduction or migrations may change with climate. Marine phenology changes are less well studied than distribution shifts, and this approach still requires validation.

Global patterns of distribution shifts predicted from temperature changes suggest that redistribution of species will be strongly affected by geographical barriers. Barriers create places where species may have nowhere cooler to go in a warming world, and newly suitable areas that climate migrants may find difficult to reach. We explore the potential effects of these global redistributions of species for patterns of diversity and global fish catches under global climate model scenarios.

March 23, 14:50 (S6-9944)

Control of plankton phenology by climate variation in a Mediterranean coastal area: Results from a long-term study (1979-2011)

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Physical processes are known to play major roles in marine plankton succession. However, few studies have addressed the mechanisms that regulate phyto- and zooplankton phenology in a context of changing climate. Here we used a unique long-term (1979-2011) time series performed in a Mediterranean coastal area unbiased by local anthropogenic pressure (PhytoCly station, Bay of Calvi, Corsica) to understand how environmental forcing affects the timing, duration and magnitude of the winter-spring phyto- and zooplankton blooms. We showed that phyto- and zooplankton blooms were bottom-up controlled by the establishment of favourable abiotic conditions, *i.e.* nutrient replenishment by vertical mixing under specific water temperature and wind conditions, for which thresholds were defined. According to the intensity of winter characteristics, there were strong differences in both the abundance and composition of phyto- and zooplankton during the winter-spring period. Our study is consistent with the recent reports that, when occurring, diatoms peaks were added to the initial phytoplankton groups instead of replacing them. In contrast, zooplankton groups followed a replacement sequence. Based on the results provided by our time series, we show that plankton phenology in the Bay of Calvi is highly controlled by climate variation and exhibits contrasted patterns in response to different scenarios of environmental forcing.

March 23, 15:10 (S6-9997)

Spatio-temporal variability of synchronicity between ice retreat and phytoplankton blooms in the polar regions

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Organisms in the earth's polar regions are adapted to the strong seasonality of environmental forcing. A small timing mismatch between biological processes and the environment could potentially have significant consequences for the entire food web. Climate-induced changes in ice coverage and ice retreat timing can potentially affect the timing of primary production, but the spatio-temporal pattern of synchronicity and potential causality have not been fully examined. Increasingly available satellite datasets of sea ice and ocean color allow us to assess the synchronicity and explore potential causalities. Results from our analysis suggest that the timing of ice retreat has a strong impact on the timing of phytoplankton blooms over most of the polar regions: earlier ice retreat is generally associated with earlier onset of phytoplankton bloom. However, there is also significant spatial variability in the synchronicity. In this study, we will also assess similarities and differences between the Arctic and Antarctic systems, propose underlying mechanisms for the variability, and discuss potential implications for higher trophic levels in the polar ecosystem.

March 23, 16:00 (S6-9871)

Diversity and phenology changes of *Calanus* in the south-western Norwegian Sea, 1990-2014, linked to ocean climate

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The south-western Norwegian Sea is characterized by an inflow of warm and saline Atlantic Water (AW) from the southwest, whereas cold and less saline East Icelandic Current Water (EICW), of Arctic origin, flows in from the northwest. These two water masses meet and form the dynamic Iceland Faroe Front (IFF). In this region, the copepod *Calanus finmarchicus* is the dominant zooplankton species and the key link between the higher and lower trophic levels. Since 1990, regular sampling of zooplankton, Chl-*a* and hydrographic conditions have been carried out along a transect covering both water masses and the front while the flow field has been monitored by moorings and satellite altimetry. Observations show that there is a spatial difference in the population dynamics of *C. finmarchicus* south and north of the IFF. Previously, the main reproductive period started earlier in the AW compared to the EICW, resulting in different life cycles and stage compositions in the two water masses. However, since 2003, this pattern has weakened and now only a vague phenology difference exists. Simultaneously, *Calanus hyperboreus*, which was a common species in the cold EICW prior to 2003, has become rare. In this study, these changes in phenology and diversity are linked to changes in hydrographic properties as well as in the flow field, both of which may be affected by future climate change.

March 23, 16:20 (S6-10252)

From large scale climate variability to individual character changes in coastal invertebrates: The case of NAO and of the daily growth of the scallop, *Pecten maximus*

Clément LeGoff[2], Yves-Marie **Paulet**[1], Aurélie Jolivet[1], Ronan Fablet[2], Stéphane Pouvreau[3], Bertrand Chaperon[3] and Christophe Cassous[4]

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Many studies tempt to address the impact of global change, and particularly of climate anthropogenic changes, at very local scales, as those of coastal ecosystem dynamics or species distribution shifts. We have tried to ask this key issue, *i.e.* the downscaling of climate model, using a very acute indicator of individual functioning: the daily growth of a marine bivalve, Pecten Maximus. In this species studied from 1987 to now in the Bay of Brest (France), growth is characterized by the faculty of making striae in their shell. Previous studies have shown that the rhythm of striae deposition is daily, allowing the drawing of yearly individual growth curves very relevant for seasonal and year to year variability analysis. This long time series of daily growth is analyzed in comparison with climatic variability at the North Atlantic scale, using synthetic indicators of pressure situation linked to the North Atlantic Oscillation. It appears clear links between atmospheric process at large scales and biologic responses of the scallops in a coastal embayment, opening the door to forecast and retrospective studies of climate variability impact on coastal systems.

March 23, 16:40 (S6-10208)

Seasonal forecasts for the timing of lobster landings

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American lobster supports one of the most valuable fisheries in the US, and the landed value in Maine alone exceeds $420M. There are currently no restrictions on when Maine lobstermen can fish, and this leads to a strong annual cycle with catches peaking in late summer. When this annual cycle is disrupted, it can impact the supply and ultimately the price of lobsters. During the record warm conditions in 2012, lobster landings ran three weeks ahead of normal. Combined with higher than normal landings from the spring Canadian fishery, the early landings in 2012 led to a collapse in price that severely stressed the fishery in Maine. Based on this experience, we have been developing seasonal forecasts for the timing of lobster landings in Maine. Using temperatures at 20m from buoys in the Gulf of Maine, we can reliably forecast in April the date when lobster landings will begin to rapidly increase. The 2-3 month lead-time provides some advance warning to dealers and processors of when their capacity needs to be ready and to fishermen of potential price impacts such as we observed in 2012. We are currently working to push the forecasts earlier into the year using statistical models and NOAA's seasonal temperature forecasts. We are also working with the lobster industry to develop other forecast products to help this industry adapt to the rapid changes underway in the Gulf of Maine.

March 23, 17:00 (S6-9856)

Warmer winters and shifting spawning phenology in sole

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Climate change is affecting fish populations in multiple ways with much attention having been devoted to changing distributions and productivity, but far less to the effects on phenology of fish. This might be because ship-based scientific surveys usually take place only once or a few times per year, but not year-round. Here we demonstrate shifts in the date of peak spawning in sole *Solea solea*, based on maturity data in monthly fish samples collected from UK and Dutch commercial fisheries since 1970. Four out of seven stocks examined showed a significant long-term trend towards earlier spawning (Irish Sea, east-central North Sea, southern North Sea, eastern English Channel) at a rate of 1.5 weeks per decade. The other three stocks (Bristol Channel, western English Channel and western-central North Sea) failed to show a relationship, but the available time series for these stocks were short (<10 years). Sea surface temperature during winter significantly affected the date of peak spawning, with warmer winters leading to earlier spawning. Because data on maturity stages are collected routinely and year-round for many commercial fish stocks worldwide, we suggest that our approach to study phenological change may be applied more widely.

March 23, 17:20 (S6-10082)

The roles of plasticity and adaptation in spawning time of Atlantic cod (*Gadus morhua*): Explaining phenology and making predictions in a changing climate

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Spawning time is thought to evolve to allow offspring to overlap in time and space with beneficial conditions for growth, development and survival. Mismatch between larval timing and *e.g.* food may result in high larval mortality and reduced productivity. The degree of mismatch will depend on the differing climate responses of predator and prey species, including potential mitigative mechanisms such as adaptation or distribution shifts. Thus, a species' production will depend on its capacity to tolerate and/or adapt to environmental conditions relative to other species in the environment. Atlantic cod (*Gadus morhua*) populations exhibit remarkably similar life histories despite spanning wide ranges in latitude (40 to 80°N) and climate (*e.g.* -1 to 20°C). In previous work, we demonstrated that temperature-standardized spawning time (*i.e.* the thermal constant of spawning) shows systematic and parallel declines with increasing latitude for populations on both sides of the Atlantic (Neuheimer & MacKenzie, in press, Ecology). Here we explore these patterns as evidence of adaptation (*i.e.* countergradient variation) to growing season timing by comparing estimates of first-feeder- and prey-timing proxies for populations across the species' range. We discuss the implications of our results for trends in spawning time, match-mismatch and resulting production both in the past and future.

March 23, 17:40 (S6-10086)

Projected mismatches between the phenology of phytoplankton blooms and fish spawning based on the GFDL Earth System Model (ESM2M)

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Climate change may have differing effects on the phenology of phytoplankton blooms and fish reproduction, since distinct oceanic processes influence these events. This could lead to increased mismatches between the occurrence of larval fishes and their prey, with negative consequences for fisheries. The GFDL Earth System Model (ESM2M) was used to examine fish and phytoplankton phenology under the RCP 8.5 climate change scenario. By the end of the 21st century, phytoplankton blooms at latitudes >40°N occurred on average 16.5 days earlier. Widespread changes in phytoplankton phenology were not observed in subtropical and equatorial regions. The following assumptions were made to model the spawning phenology of temperate, epipelagic fishes: (1) During a baseline period, we assumed that on average fishes spawned synchronously with the spring bloom; (2) Interannual variations in spawning phenology reflect changes in cumulative degree days between the time of the annual SST minimum and the spring bloom; (3) In absence of genetic or behavioral adaptations, the threshold of degree days that triggers spawning will remain unchanged in the future. For fishes whose spawning grounds are defined by stable geographic features (*e.g.*, rivers, estuaries), shifts in phenology occurred twice as fast as phytoplankton at latitudes >40°N. These fishes spawned before the phytoplankton bloom across 80% of the study area. Seasonal mismatches between fishes and phytoplankton were less widespread in simulations where fishes shifted their spawning ground location in response to temperature. Nevertheless, sizable mismatches between trophic levels persisted across parts of the North Pacific and Arctic.

S7 Oral Presentations March 27
Evolutionary response of marine organisms to climate change

March 27, 11:20 (S7-10195), Invited

Predicting life history changes in marine ecotherms responding to directional climate change and fluctuating productivity regimes

Robin S. **Waples**[1] and Asta Audzijonyte[2]

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Although humans have altered our environments and affected species that coexist with us for tens of thousands of years, our ability to change natural ecosystems, including the oceans, is currently increasing much faster than our ability to understand the consequences of these changes. Environmental change alters selective regimes that species experience and can be expected to elicit adaptive responses (evolution = genetic change over time; phenotypic plasticity = acclimation within the lifetime of an individual). In this talk we focus on the effects of changing temperature on life-histories of marine ectotherms. Warming oceans will generally favor earlier maturation and smaller adult size through i) higher oxygen demand and sensitivity of large individuals to increased temperature; ii) lower temperature optimum of adults compared to juveniles; iii) altered mortality regimes at higher temperature; and iv) different responses of growth and maturation to shifts in temperature. From these general rules we can predict the trajectory of life-history changes in many marine ectotherms. We consider the following questions: What are the consequences of these life history changes for population productivity and resilience? How will these changes interact with the effects of size- and age-selective harvest? Can species effectively track directional climate change when decadal-scale environmental fluctuations (Pacific Decadal Oscillation, North Atlantic Oscillation) complicate the long-term trend? What management strategies can maximize the capacity of marine species to adapt to climate change? What demographic or genetic methods can be used to monitor adaptive responses by marine species to climate change?

March 27, 11:50 (S7-10121)

Early survival of coral juveniles and initial uptake of algal symbionts in the world's hottest reefs

David **Abrego** and Emily Howells

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Symbioses between corals and microalgae are fundamental for coral reef health. The genetic identity of algal symbionts often underpins the response of corals to environmental stress and there is considerable debate about how the composition of algal symbionts may change as the oceans get warmer. To address this question, we compared coral symbioses from an extremely hot environment in the Arabian Gulf with a nearby milder reef in the Indian Ocean. Firstly, we identified differences in the species of algal symbionts in adult coral populations at each location. Secondly, we identified the species of algae taken up by a common pool of non-symbiotic juvenile deployed to these two environments and the influence of algal species on the survival of juvenile corals during the warmest weeks of the year. Survival rates under the Arabian Gulf summer were 34% lower than in the Indian Ocean reflecting the dramatic differences in thermal conditions between these reefs. The genetic identities of algal symbionts in adult and juvenile coral populations at both reefs will be discussed in terms of their potential implications for changes to these symbioses and future coral survival as oceans warm up.

March 27, 12:10 (S7-10006)

Robust monitoring of genetic effective population size in a changing environment

Andrew Thomas **Jones**[1], Shane Lavery[2], Jennifer Ovenden[3] and You-Gan Wang[1]

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Genetic effective population size can be regarded as a measure of how a population is potentially able to evolve to meet the challenges of a changing environment. However, genetic effective size also depends on the population's behavior and life history which may also be changing due to environmental pressures.

While there has been a great deal of work in recent years on the relationship between life history parameters and the link between genetic effective size and census population size, there has been less work on how uncertainty and changes in population characteristics could affect the accuracy and precision of effective population size estimates made on real populations.

This study investigates these issues through a sensitivity analysis on how changes in population parameters can affect estimates of genetic effective size made using commonly available estimation techniques under a variety of sampling schemes. Examples will be given from a population of snapper (*Pagrus auratus*) in a marine reserve in New Zealand.

March 27, 14:00 (S7-9887)

Adaptation of coral symbioses to extreme temperatures

Emily **Howells**[1], David Abrego[2] and John Burt[1]

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Understanding the potential for phenotypic or genetic adaption to warming seas in corals is challenging due to the interacting responses of animal host and symbiotic algae that define tolerance traits as well as long host generation times which prohibit cross-generational studies. To overcome these challenges we characterized the contribution of host and symbiont to thermal tolerance in corals that have already experienced considerable warming on par with end-of-century projections for most coral reefs. Thermal responses in corals from the hot Arabian Gulf (36°C annual maximum) were compared with conspecifics from a milder Indian Ocean locality (33°C annual maximum). Arabian Gulf corals had rates of survival at elevated temperatures (33-36°C) in both the symbiotic adult life-stage (40% higher) and the non-symbiotic larval stage (32-49% higher). In adult Arabian Gulf corals, symbiont photosynthetic performance was relatively unaffected by elevated temperature in contrast to Indian Ocean corals in which symbiont performance declined by up to 80% with increasing exposure to 33 and 36°C. Variation in tolerance limits between the Arabian Gulf and Indian Ocean corals was maintained after long-term (6 month) acclimatization to a common ambient environment and underpinned by substantial genetic divergence in both the coral host and algal populations. These findings indicate that genetic adaptation in both symbiotic partners enables corals cope with the extreme temperatures in the Arabian Gulf. Thus persistence of coral populations elsewhere will likely be determined by the rate of co-evolved thermal tolerance rather than the responses of a single symbiotic partner.

March 27, 14:20 (S7-9945)

Population genetic signatures of a recent marine range extension

Jorge E. **Ramos**[1], Gretta Pecl[1], Natalie A. Moltschaniwskyj[3], Jayson M. Semmens[1] and Jan M. Strugnell[2]

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Shifts in species distribution are one of the most commonly documented responses to environmental change. Knowledge of the level of connectivity, genetic structure and diversity among populations at the historical and extended range of a species distribution is fundamental to understanding the genetic consequences of such range shifts. The southwards extension of the East Australian Current has been associated with the recent shift in distribution of several dozen marine species along south-eastern Australia. One of these species is *Octopus tetricus* which has extended its distribution several hundred kilometres polewards. Seven microsatellite loci were used to examine the population connectivity, genetic structure and diversity of *O. tetricus* throughout its range. Significant genetic differences were detected between the historical distribution and the range extension zones. The population at the range extension was sub-structured, contained relatively high levels of self-recruitment but was also found to be sourced by migrants from along the entire geographic distribution. Levels of genetic diversity were comparable between the range extension zone and the historical distribution zone and there was no evidence of a bottleneck at any site. However, the estimated effective population size was smaller at the range extension zone compared to the historical distribution zone. The range extension of *O. tetricus* may be positively influenced by high and constant gene flow from different areas and by high genetic diversity, which may allow *O. tetricus* to cope with accelerated ocean warming by favouring adaptation, establishment, and likely long-term persistence in the range extension zone.

March 27, 14:40 (S7-10171)

Different responses to water temperature in two distinct groups of Pacific cod (*Gadus macrocephalus*) inhabiting around Japan

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Shifts in species distributions in marine systems are currently reported, thus, comprehensive analyses of the effects of climate change require an interdisciplinary approach. Animal distribution data such as fishery catch and environmental variables can be combined to assess and predict how animals interact with their environment. Our question is whether organisms will show rapid evolutionary responses to the current warming. The answer to this question will give us clues for contributing to sustainable fisheries. Pacific cod, *Gadus macrocephalus* is one of the largest fisheries in the North Pacific. Using multiple nuclear markers, two distinct groups were observed around Japan. We believe that those genetically different groups are separated by environmental differences such as water temperature, bathymetry, or currents. Our hypothesis is there are different responses to their environments and expect those distinct groups may have different responses to the predicted environment. Here we analyzed levels of biomass, distribution and interaction between environments such as water temperature obtained from adjacent waters in Japan recorded for 20 years. GAMM was used and distribution patterns were compared to observe particular differences. We found that one group collected from the Northern Japan tends to have high distribution around 250 m and decreases their biomass with increasing water temperature. In contrast, the other group inhabit in the southern area showed shallower distribution and possible resistance to higher water temperature. Therefore, considering both population structure and responses to the environment is one of the strong tools for predicting their future trends and conducting efficient management.

March 27, 15:00 (S7-10251)

Effects of global changes in health and disease of carbonatic holobionts

Fabiano **Thompson**[1], Christine Paillard[2], Yves-Marie Paulet[2], Flavia Nunes[2], Stéphanie Bordenave[3], Gilberto Amado Fo[4], Leonardo Tavares[4], Rodrigo Moura[1], Paulo Salomon[1], Giselle Cavalcanti[1], Arthur Silva[1] and Carlos Rezende[5]

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While temperature may influence bacterial virulence and health of corals, rhodoliths, mollusks and other carbonatic holobionts, the exact mechanisms are not totally understood. We will present and discuss recent data on coral and mollusks diseases which are related to increased seawater temperature and discuss some possible mechanisms of temperature inducing virulence in marine pathogens or/and immune-depression in carbonatic holobionts. Temperature appears to play a central role in the induction of pathogenicity gene expression. In addition, acidification may interfere on organic matter availability, calcification and growth in marine systems. Recent studies leveraging on omics technology, biomineralization processes analysis, and organic chemistry have shed light on the possible responses of holobionts and systems to acidification. Dramatic changes in microbiomes, gene expression, and organic compounds seem to follow after ocean acidification.

S8 Oral Presentations, Day 1 March 25
Climate change impacts on marine biodiversity and resilience

March 25, 11:20 (S8-10262), Invited

We punch nature and it will punch us back: Human impacts on marine biodiversity and their feedbacks

Camilo **Mora**

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Human impacts on biodiversity are leading to extinction that largely exceeds natural background rates. This is impairing the capacity of ecosystems to deliver basic goods and services to humanity; and in turn, it is undermining efforts to improve human welfare, especially for the nearly one billion people that go hungry every day. In this presentation, I describe global scale analyses into the impacts of climate change on marine ecosystems and how they are making a large fraction of the world's human population vulnerable to loosing important sources of revenue, food and jobs. I will also present the results of a simple energetic model that suggest that even if human consumption is reduced, we will still be in a ecological deficit and that only scenarios that include natality reductions do quickly balance our ecological footprint on Earth. For our generation will be the decision between a crowded world or a better world.

March 25, 11:50 (S8-9787)

Contrasting effects of sustained warming and heat waves on ecosystem resilience: Climate variability disrupts producer-consumer relationships decreasing resilience to multiple disturbances

Giulia **Ghedini**, Bayden D. Russell and Sean D. Connell

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Gradual changes in mean climatic conditions (*e.g.* sustained warming, ocean acidification) may modify the strength of producer-consumer relationships through the provision of resources (*e.g.* temperature, CO_2). If the increase in productivity is compensated by a proportional increase in consumption, the relative strength of the interaction is maintained with no overall outward change for the system. We hypothesized that extreme events (*e.g.* heat waves) may disrupt producer-consumer relationships by failing these compensatory mechanisms, particularly if such events are accompanied by differential mortality of species. We tested this hypothesis on a key interaction in kelp forests (*i.e.* gastropod grazers consuming turf-forming algae) simulating a heat wave event at current and future temperature and CO_2 conditions. While turf algae are opportunistic species that increase growth rates when resources are added to the system, grazers can compensate for turf growth by increasing their consumption rates under sustained warming conditions. Abrupt changes in temperature provoked by heat waves may strongly disrupt this interaction by differentially affecting grazers and primary producers. When the compensatory response fails under a heat wave, consumer control of opportunistic species is hindered resulting in a rapid decrease in ecosystem resilience. Extreme events, especially when in combination with other disturbances (*e.g.* sustained warming, ocean acidification), may, thus, trigger rapid changes in ecosystem structure and function which may not be easily reversed.

March 25, 12:10 (S8-9831)

Acclimation capacity of tropical and temperate coastal organisms

Inês **Leal**[1], Vanessa Mendonça[1], Diana Madeira[2], Luís Narciso[1], Mário S. Diniz[2], Augusto A.V. Flores[3] and Catarina Vinagre[1]

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Understanding the impact of global warming on biodiversity is one of the most important challenges faced by mankind. It is important to identify which ecosystems and species are more vulnerable to this threat. Such vulnerability may vary across latitude and will depend mainly on an organism's acclimation capacity, which remains unknown for most species. Thermal studies regarding different taxa from different latitudes have shown that tropical organisms are the ones living closest to their thermal limits. Also, species with the greatest tolerance to high temperatures have been shown to display the smallest acclimation capacity, which may place tropical species in greatest jeopardy from further warming compared to higher latitude counterparts. In this study, we compared the acclimation capacity of tropical and temperate intertidal organisms belonging to the Palaemonidae, Grapsidae, Blenniidae and Gobiidae families. We estimated the critical thermal maximum (CTMax) at control temperature and (1) after 30 days at "control +3ºC", simulating the future summer temperature, and (2) after 10 days at "control +6ºC", simulating a future heat wave. All species tested have some acclimation capacity ($CTMax_{Trial}$ - $CTMax_{Control}$), with the exception of the fish from the Gobiidae family, which did not acclimate. The tropical species tested showed a lower acclimation capacity than their temperate counterparts. Given that tropical rocky shore organisms are already living very close to their thermal limits and that their acclimation capacity is limited, it is likely that the impacts of climate warming will be evident sooner in the tropics than in the temperate zone.

March 25, 14:00 (S8-9880)

Rapid emergence of marine ecosystem stress

Stephanie A. **Henson**[1], Claudie Beaulieu[2] and Jorge L. Sarmiento[3]

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Marine ecosystems provide multiple services of high economic and social value, such as regulation of Earth's climate via the uptake and storage of atmospheric carbon dioxide. Significant impacts on marine ecosystems are likely to occur when climate change pushes the environment outside the range of natural variability to which organisms are adapted, and where multiple stressors coincide the effect is likely to be particularly pronounced. Here we quantify when the climate change signal in the marine stressors temperature, pH, interior oxygen concentration and primary production emerges from the range of natural variability. By analysing an ensemble of models we find that, within the next 15 years, the climate change-driven trend in multiple ecosystem stressors emerges in ~ 60% of the ocean and propagates rapidly to encompass 99% of the ocean by 2050. However, we also demonstrate that the exposure of marine ecosystems to climate change-induced stress can be drastically reduced via climate mitigation measures. Comparison of high and moderate emission scenarios demonstrates that with mitigation the proportion of ocean susceptible to multiple stressors within the next 15 years can be slashed from 60% to just 4%. Mitigation dramatically slows the speed at which climate change emerges, allowing an additional ~ 30 years for marine ecosystems to adapt to the new environment, likely resulting in higher rates of survival and biodiversity, and fewer species extinctions.

March 25, 14:20 (S8-9898)

Modelling ecological tipping points and road-testing management strategies for increasing marine ecosystem resilience

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Other authors to be acknowledged in presentation: Nick Ellis, Laura K. Blamey, Elisabetta B. Morello, Ana Norman-Lopez, William Robinson, Miriana Sporcic, Hugh Sweatman, Malcolm Haddon, Natalie Dowling

Adaptive response to abrupt changes in the state and organisation of ecosystems, and planning for their occurrence, requires an understanding of the underlying drivers and system responses as well as appropriate monitoring. Our multispecies modeling and quantitative analyses show that abundances of a range of marine predators become more variable as prey numbers decline, which may be a useful indicator that a system is approaching a tipping point. This talk (1) presents examples of the use of multispecies models to advance our ability to anticipate or deal with major ecosystem shifts, (2) provides examples of how the outputs can be used to inform monitoring and management, and (3) describes two examples of the use of management strategy evaluation (MSE) to test the performance of alternative marine monitoring and management strategies to detect and respond to abrupt ecological changes caused by climate change. Our study demonstrates the utility of MSE to test the performance of alternative harvest strategies in meeting fishery objectives; this includes the ability to manage through climate variability and change, and meeting management objectives pertaining to resource status and fishery economic performance. We draw on a range of examples, including Australia's northern prawn fishery, Torres Strait and Great Barrier Reef (GBR) sea cucumber fisheries, and outbreaking crown of thorns starfish on the GBR.

March 25, 14:40 (S8-9929)

Assessing vulnerability of marine species to climate change in the world's oceans: Combining biological traits, climate projections and species distribution modelling

Miranda C. **Jones** and William W.L. Cheung

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Climate change has been predicted to cause poleward shifts in the distribution of marine species, with implications for global patterns of biodiversity as well as potential fisheries' catch. However, a species' response to climate change will also depend on particular biological characteristics, or traits, that may moderate its vulnerability. Here we draw on species' biological traits and ecological characteristics, as well as their potential biological responses, combining them using a fuzzy logic expert system approach to predict species' vulnerabilities to climate change. Projections of changes in ocean conditions under different climate change emissions scenarios are used to calculate the level of climate change exposure across the current range of each species, obtained using species distribution models. Data on biological traits are obtained from online databases such as FishBase and SeaLifeBase and combined with ecological and habitat characteristics to represent a species' sensitivity and its adaptive capacity to climate change. The fuzzy logic expert system then synthesizes the information to calculate an index of climate change vulnerability for each species. Uncertainty and the sensitivity of the approach to variation in the modelling procedure are also considered. We thereby evaluate the global distribution of climate change impacts on the marine environment, using a set of commercially targeted species as a case study, and identify hotspots of climate change vulnerability.

March 25, 15:00 (S8-9931)

The role of species interactions in determining ecosystem resistance to an increasingly modified world

Laura J. **Falkenberg**[1,2], Bayden D. Russell[1,3] and Sean D. Connell[1]

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Mitigating the ecological consequences of change in environmental conditions may be achieved where key species, and their interactions, are retained. Of particular importance are foundation species, as their capacity to influence conditions can stabilise entire ecosystems. The potential exists, however, that if localised human actions lead to the loss of such key species, their role in modifying conditions may be disrupted and ecosystem change more strongly favoured. A model system that enables testing of this concept is temperate marine ecosystems and the components of canopy-forming kelp and opportunistic mat-forming algae (*i.e.* turfs). While persisting in some areas, there has been historical loss of kelps along many coastlines, which have subsequently become dominated by mat-forming algae. Given this patchy occurrence of contrasting habitats, we conducted a manipulative mesocosm experiment to test the relative effects of global change conditions, specifically future CO_2 and elevated temperature, where kelp canopies were either present or absent. We identified that while modified climate conditions positively affected mat-forming algae in the absence of canopies, this change was restricted where canopies were present. These results indicate that although there have been localised changes in habitat structure in some regions, if key species are present when future conditions manifest they may be able to restrict the impact of globally-driven climate change. Management of key species via retention or re-introduction may, therefore, represent an approach to facilitate the persistence of historical ecosystem states, even under forecasted conditions otherwise anticipated to increase the likelihood of their loss.

March 25, 15:20 (S8-10213)

Impacts of climate on marine community structure across North America

Ryan D. Batt and Malin L. **Pinsky**

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Globally, changes in water temperatures have been hypothesized to lead to a redistribution of marine taxa and subsequent shifts in species diversity. Coastal taxa have been found to track climatic conditions, but variability around this relationship suggests that taxa are not moving as cohesive communities. We examined the composition and movement of 365 coastal assemblages consisting of over 1800 species from 10 regions around North America over the past five decades, as recorded within bottom trawl surveys. We found that some communities were relatively stable over time, whereas others showed substantial variation through time. In particular, high-latitude communities were more variable than low-latitude communities, a pattern that parallels rapid warming at high latitudes. Furthermore, spatial trajectories of climate velocity show promise for understanding and predicting changes in local species richness. These results complement and extend single-species analyses and suggest that changes in coastal communities are predictably associated with changing climate. These patterns of community reorganization may be more predictable than single-species responses to changing climates.

March 25, 16:10 (S8-10059)

Marine regime shift detection and attribution

Claudie **Beaulieu**[1], Renata Stella Khouri[1], Harriet Cole[2], Stephanie A. Henson[3] and Andrew Yool[3]

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The Earth's climate system and ecosystems often exhibit non-linear behavior and abrupt changes, the latter especially challenging societies ability to adapt. Marine regime shifts can disrupt the services these ecosystems provide to humans and thus, are of great socioeconomic concern. In marine ecosystems, drivers such as climate change or overfishing can trigger abrupt changes. Regime shifts can also be generated randomly from within the system, through long-memory processes arising from the ocean's slow response to weather forcings. Here we propose a methodology to detect abrupt changes and distinguish between forced and unforced (*i.e.* random) reorganization of the system. We focus on marine plankton as they are sensitive indicators of changing environment. We apply our shift detection methodology to phytoplankton abundance observations in the North Atlantic, where a late 1980s regime shift has been previously suggested. We also propose an attribution approach to identify specific physical and biological drivers and demonstrate it using a suite of marine ecosystem models of varying complexity. We investigate the ability of the selected marine ecosystem models to simulate the late 1970s North Pacific regime shift and show how the shift is propagating through the ecosystem.

March 25, 16:30 (S8-10161)

Environmental pressure drives functional diversity of fish assemblages in a temperate brackish system

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Biological diversity can impact ecosystem functions such as productivity, nutrient recycling and the resilience of ecosystems to perturbation. There is an increasing awareness that ecosystem functioning do not directly depend on the species composition but instead on the species functional trait distribution. The occurrence of these traits and their distribution in communities permits to link between organisms and ecosystem functioning. The Baltic Sea, one of the largest brackish body, is characterized by a strong gradient in salinity from euhaline water in the Kattegat to freshwater in the Bothnian Bay. A consequence of this environmental pressure is reflected in the decreasing trend in species richness along the gradient. However, there is still a knowledge gap on the species traits distribution and on the mechanism that shape the communities diversity. Using a trait-based approach, the diversity and the mechanism influencing community composition of fish assemblages was studied. We found that the species co-occurring were globally more functionally similar than expected by random and we found a strong influence of the environment on the distribution and traits composition of the communities. The assembly mechanisms are also found to be scale dependent. The functional richness and composition of the fish communities was following the environmental salinity and temperature gradient. Due to the climate change, the salinity of the Baltic Sea is predicted to decrease. Using the observational data along the gradient can permit to foresee the spatial fish community composition of the studied area under climate change scenarios.

March 25, 16:50 (S8-10096)

Size structure, diversity and resilience: Observations and predictions in the context of climate change

Katherine E. **Mills**, Andrew J. Pershing and Arnault Le Bris

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The size structure of a population or community has important implications for resilience in the face of perturbations such as those that will be imposed on ecosystems by climate change and fishing pressure. Macroecological analyses suggest that marine community properties including size structure and diversity not only influence resilience to climate change but are expected to be directly impacted through changes in temperature and primary production. In this presentation, we will (1) describe shifts in the size structure of the fish community and a key commercial species—Atlantic cod—on the Northeast Shelf of the United States, (2) discuss relationships between size structure and ecosystem characteristics, including temperature and fishing, and (3) present modelling results demonstrating the implications of changes in the size structure for the resilience of Atlantic cod populations.

The metabolic theory of ecology incorporates well characterized relationships between temperature, metabolic rate, and body size, and these relationships may provide a basis for predicting community properties such as size structure and diversity under future climate scenarios. We will evaluate how the relationships between these factors observed on the Northeast Shelf fit expectations established by the metabolic theory of ecology. The predictive capacity afforded by these relationships will also be assessed as a potential avenue for forecasting climate impacts to the size structure, diversity and resilience of fish communities—essential information for guiding fishery and marine ecosystem management under climate change.

March 25, 17:10 (S8-9803)

Modeling of the pattern of mangrove resistance to sea-level rise

Denilson **da Silva Bezerra**, Silvana Amaral, Milton Kampel, Eduardo Rodrigues and Fabricio Brito Silva

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The mangrove is vulnerable to sea-level rise, due to its intermediate position between the sea and the continent. The Brazil has, simultaneously, the second largest total area, and the largest area of continuous mangrove present in the Brazilian north coast. The present study proposes a methodological approach to simulate the resistance pattern of the mangrove to sea-level rise, using spatially explicit modeling based on cellular automata. The proposed model is called the BR-MANGROVE; initially we present the conceptual model, the rules for the interaction between the elements and the methodological procedures for computer implementation. The simulation considers eighty-eight events of elevation from 0.011 to 0.97 m according an arithmetic progression of reason 0.011 m for the time interval from 2012 to 2100. The case study area is the Maranhão Island which contains extensive mangrove area, and is densely occupied. The results demonstrated that mangrove had thirteen resistance patterns, where the first was characterized by an elevation range from 0.01 to 0.13 m for the period 2013-2024. In this interval, the mangrove area remained approximately constant, with values of the order of 17,711 ha for the total area, and 16,916 ha of remaining area, which corresponds to 4.49% (795 ha) of expansion. After the first resistance pattern, mangrove showed twelve subsequent patterns of resistance and decline of area until the end of the simulation. The results obtained suggest that modeling experiments can be used to promote a better understanding of patterns of the mangrove responses to potential events of sea-level rise.

March 25, 17:30 (S8-10112)

Extreme events of cold water and high light irradiance are responsible of massive bleaching in coral reefs

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Since the 1980´s, extreme climate variations as high sea surface temperature (SST) events have been correlated with coral bleaching and mortality around the world. The National Oceanic Atmospheric Administration of the United States monitors the conditions of coral reefs through the “Coral Reef Watch” program, estimating the cumulative thermal stress (anomalies >1°C over the maximum summer average) as an indicator of potential bleaching. To track this condition, their predictions are based on a thermal index (degree heating weeks; DHW´s) that sum the positive thermal anomalies of the previous three months to a given date. During the last decade, anomalously cold SST events were reported, which caused similar impacts on reefs and its residents as warm events. However, there is not a methodology analogous to the DHW index to estimate the thermal stress level triggered by cold water on corals. In the Tropical Eastern Pacific (TEP), a threshold of 1ºC below the minimum average SST in coral reefs do not adequately forecast low temperature bleaching, suggesting that other factors are involved. This study show that with satellite data of SST and photosynthetic active radiation, the combination of extreme events of low temperature and high solar irradiance can predict massive coral bleaching on the TEP. We propose that a thermal threshold is not enough to detect potential coral bleaching caused by cold, but also a light limit exists; this way, the simultaneous presence of an anomalies of temperature <-1° and >1° of irradiance simultaneously are the trigger for cold-water coral bleaching.

March 25, 17:50 (S8-10031)

Ecological impacts of species range shifts: Identifying the good, the bad and the uncertain

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Sustained contractions and extensions in species distributions are widely acknowledged as a fingerprint of climate change in natural systems, and have been reported in a range of marine ecosystems worldwide across tropical, temperate and polar latitudes. Despite a significant proportion of species (18-80%) within many marine ecosystems shifting their distributions polewards, ecological studies essentially focus on individual species overlooking the broader impacts of co-occurring interacting species shifts on ecosystem structure and functioning. Direct and indirect effects of such species redistribution on marine ecosystem dynamics, and the flow-on effects for human coastal communities, are difficult to understand and predict. Here we use qualitative modelling of system feedback, informed by available information about temperate reef community structure and expected climate-driven changes in species abundance, to develop a general understanding of the potential impacts of a suite of range-shifting species in the rapidly warming waters off Tasmania, Australia. In this region 30% of the fish fauna that occur inshore, plus several dozen invertebrate species, algae and plankton communities have exhibited evidence of distributional shifts. We qualitatively simulate range shifts in Tasmanian waters as long-term changes in species abundance (*i.e.* increase or decline associated with a range extension or contraction, respectively) and identify those range-shifters that can significantly affect reef community dynamics. We conclude with practical advice to guide future research and monitoring, and adaptive management of these rapid changes. Our study illustrates how qualitative modelling can help discriminate between range-shifting species with marginal ecological impacts and those that can induce trophic cascades affecting overall ecosystem structure and functioning.

S8 Oral Presentations, Day 2 March 26

March 26, 09:00 (S8-9901)

Testing a climate adaptation strategy for vulnerable seabirds based on prioritisation of intervention options

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Many iconic marine species, such as seabirds, marine mammals and reptiles are recovering from past harvesting activities, and, although widely protected, the recovery and continued persistence of many species and populations remains under threat from present-day anthropogenic activities. Management actions, accordingly, tend to focus on reducing existing demonstrated stressors, however evidence is accumulating that some species will be negatively impacted in the future by climate change. Recent work shows that the endemic Tasmanian shy albatross is likely to be adversely effected by projected change in environmental conditions under climate change scenarios. Furthermore, modelling shows that the elimination of the principal threat to shy albatross populations in the present day - fisheries bycatch - would not be sufficient to reverse projected population declines. Here we present a case study in which we identify, evaluate and test intervention options in preparation for future predicted climate change impacts. We first assessed a suite of plausible adaption options using a semi-quantitative cost-benefit-risk tool, leading to a relative ranking of actions. We tested one of these options in 2014, disease control, by reducing the ectoparasite load of developing chicks using avian insecticide and comparing the survival and condition of treated chicks with those in a control plot at the end of the season. We describe the process of developing and implementing this approach and report results for this intervention designed to offset the projected effects of climate change on an iconic species.

March 26, 09:20 (S8-9930)

Long-term climate variability effects on the trophodynamics of a South American temperate estuarine ecosystem

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The trophodynamics of the Río de la Plata ecosystem at long time scale (from 1948 to 2008) using a food-web model forced by two environmental factors was simulated. Holistic indicators were used to identify ecosystem degradation, which is represented by the gain in entropy. The Atlantic Meridional Mode was the regional forcing, and the Río de la Plata runoff was the local forcing. A negative correlation between the forcing factors was detected (R^2= -0.38, df= 60), with a temporal coupling on the long-term variability of both environmental forcings. The regional forcing impacted the food-web completely or partially at inter-decadal scale or inter-annual, respectively. In turn, the local forcing affected the biomass of low trophic levels and middle ones at inter-annual scale. The occurrence of higher effects of the RdlP runoff on biomass of low trophic groups (*i.e.*, plankton) and middle ones (*i.e.*, invertebrates) were coupled with the development of seven strongest El Niño events since 1950 until 2008 (1957-59, 1965-66, 1972-73, 1982-83, 1986-88, 1991-93, 1997-98). Contrarily, the lower effects of RdlP runoff on the food-web were coupled with the occurrence of six strongest La Niña events since 1949 (1949-51, 1954-56, 1964-66, 1970-72, 1974-75, 1988-90). The entropy system and their efficiency showed two opposite phases, before and after early of the 1970 decade. During the period 1948-1972, the system showed high entropy (high degradation) and low efficiency, while the cycle was reverted after 1973 to the present, when a less extreme trend on system entropy was compensated by higher efficiency.

March 26, 09:40 (S8-9980)

Predicting ecological changes of benthic estuarine assemblages from Marine Ecoregions of Brazil through decadal climatology

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Estuaries are threatened coastal ecosystems that support relevant ecological functions worldwide. The increase of global temperature and the risks of global climate change demand efforts to understand, anticipate and avoid further damage on estuarine habitats. In this study we have reviewed benthic assemblage data from Brazilian estuaries along five Marine Ecoregions (Amazonia, NE Brazil, E Brazil, SE Brazil and Rio Grande) to critically evaluate scientific support as a basis to increase their adaptive capacity and resilience. We have compared the variability of benthic assemblages across ecoregions with a 40-year time series of temperature and rainfall data as a support for theoretical predictions on the main threats that they may face along time. We have found significant increases in temperature during the last four decades at all Marine Ecoregions of Brazil, with rainfall increase at the Southeast ecoregion. As a result, we predict changes in benthic metabolism and productivity at all ecoregions and the expansion of the range of tropical and subtropical species towards estuaries of the Warm Temperate Southwestern Atlantic. Benthic assemblages and climate oscilations vary significantly among but also within ecoregions, which suggests that processes will be affected differently between estuaries. This supports further investigations of benthic ecological processes at multiple estuaries within ecoregions in order to obtain a reasonable understanding of the natural status and future changes on estuarine habitats. The high climate variability in estuaries within the same ecoregion may lead to correspondingly high levels of uncertainty on the expected responses of benthic fauna.

March 26, 10:00 (S8-10005)

Surviving in a warming world: Acclimation of molluscs to warming is dependent on ocean acidification and thermal variability

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Future temperature and CO_2 are predicted to change the structure and function of marine ecosystems by altering rates of both primary productivity and consumption. Metabolic theories predict that increases in consumption should outstrip that of production, but this assumes that the consumers can acclimate or adapt to the changing conditions. Drawing together the results of several of our experiments assessing the effects of elevated temperature and CO_2 (ocean acidification) across both intertidal and subtidal systems, we show that the ability of herbivorous molluscs to acclimate to future conditions is context dependent; species from the more variable intertidal systems demonstrate a greater capacity to acclimate to future conditions than their subtidal counterparts. Common to both intertidal and subtidal species, however, is that temperature-driven increases in metabolic rates are maintained by increased feeding up to thermal thresholds, beyond which both metabolic rates and feeding are depressed. Interestingly, thermal thresholds are altered by elevated CO_2 in subtidal but not intertidal species. In regions where the dominant grazers are molluscs, these results suggest that the ability of grazers to compensate for increasing primary production may be dependent on the system they inhabit, and consequently their ability to acclimate.

March 26, 10:20 (S8-10038)

Future ecosystem states: Linking ecological responses to climatic extremes

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Considerable anecdotal and experimental evidence exists for thresholds in individual species and ecosystem responses to regimes of climate and extremes of weather. State changes in ecosystems have occurred in the past as a result of significant disturbance events mediated by heatwaves, cyclones, floods and so forth. While ecosystems may cycle through various stable states in response to known disturbance regimes, anticipated rates of change in climatic systems and associated extremes may exceed the individual capacities of species to respond. As the climate continues to change, researchers are increasingly being asked about the role of extreme weather events in shaping the appearance of natural ecosystems, potential for loss of species, determining the viability of fishery and agricultural systems and whether particular system thresholds have been or will soon be breached. Such information is essential for adaptation policy, planning and management. There is a need to consolidate, for example, scientific understanding of the link between climatic regimes (extent, magnitude, duration, frequency and timing), climate variability and weather extremes to changes in species survivability and alternative ecosystem states. Here, we present the results of a synthesis to identify links between ecological responses and climatic extremes, and improve understanding how climate conditions (rates of change, pre-conditions) regulate ecological responses at varying spatial and temporal scales. The synthesis will look across different systems (marine, agricultural, human health) and types of extreme climatic events, how these are defined and consider the role of climate change in driving these events.

March 26, 11:10 (S8-10115)

Effects of ocean acidification on marine species

Ivan **Nagelkerken** and Sean D. Connell

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Ocean acidification has been predicted to affect a wide number of species and ecosystems across the world. In recent years there has been a significant increase in the number of studies published on ocean acidification. However, most studies are still focused on single-species experiments, while it is likely that altered species interactions will play a key role as well. We review the literature to identify which species groups might be most at risk to ocean acidification and which taxa appear less sensitive. We also discuss how altered species interactions due to ocean acidification could modify species community structures and what the potential implications of such changes are for ecosystem functioning.

March 26, 11:30 (S8-10269)

Antarctic sea urchins can acclimate within months to rapid climate change

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The Antarctic Peninsula is subject to rapid warming and will be the first major region to become undersaturated with respect to carbonates as CO_2 increases. Organisms inhabiting shallow Antarctic seas are predicted to struggle to maintain homeostatic and biomineralising processes under these conditions. Additionally these characteristically slow growing organisms have generation times during which observable climate change could occur. Therefore the future persistence of these organisms is debatable with much of the literature predicting gross negative response.

Long-term exposures are needed to determine organismal physiological flexibility/acclimation, energy requirements and reproductive outputs. We address these needs by investigating the responses of an ecologically important benthic invertebrate that is a key component of the carbon cycle – the Antarctic sea urchin, *Sterechinus neumayeri*. These animals were reared under year 2100 IPCC forecasted carbonate saturation states and temperatures for several years and their physiological, energetic and reproductive responses assessed. In addition F1 sea urchins were reared under these conditions after short and longer parental exposures demonstrating the importance of widening parental exposure times in laboratory experiments.

We show that physiological acclimation to laboratory induced rapid climate change can be achieved within months but highlight that different responses can be obtained from short and long-term studies. Careful consideration is therefore needed when making predictions on organismal responses based on short-term data. This is the first study to assess the long-term (multi-year) impacts of predicted 2100 ocean acidification conditions on an Antarctic organism and contributes to current understanding of organismal responses under a future climate.

March 26, 11:50 (S8-9829)

Invasive, non-native and nuisance species and how climate change might contribute to their spread

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Changes in the oceans caused by climate change can indirectly affect biodiversity and ecosystems by increasing the rate of spread of invasive, non-native and nuisance species. As climate change increases sea temperatures in particular, the areas that some of these species can thrive expand, and can give them a competitive advantage over native species. Bioclimate envelope models, using fine-scale climate projections, are used here to determine the areas in which non-native and nuisance species may be able to live and reproduce with future climate change. Case studies include harmful algal blooms, invasive shellfish, comb jellies and sea weeds. So far, however, similar studies have been based on global climate models, which have a coarse resolution when applied at a local scale. In this study, we use high-resolution climate outputs from regional UK shelf sea models in order to give higher resolution projections for suitable environmental conditions for non-native and nuisance species in northern Europe. For benthic species, substrate type has also been included to show which locations the organisms may be able to settle and proliferate. There can be negative consequences to invasions by non-native and nuisance species, by smothering, predating or outcompeting native species. By understanding which invasive species may be able to expand more rapidly in the future, prevention and removal methods can be prioritised and targeted.

March 26, 12:10 (S8-10237)

The metabolic response of marine copepods to environmental warming, ocean acidification and food deprivation

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Marine copepods, tiny water flea-like crustaceans, are central to the productivity and biogeochemistry of many marine ecosystems. However, the direct and indirect effects of climate change on their metabolic functioning remain poorly understood. Here, we use metabolomics, the unbiased study of multiple low molecular weight organic metabolites, to demonstrate how the physiology of oceanic copepods, *Calanus* spp., is affected by end-of-century global warming and ocean acidification scenarios. We report that the physiological stresses associated with short-term food deprivation, a natural occurrence that is being exacerbated by global warming, greatly exceed those caused directly by seawater temperature or pH perturbations. This highlights the need to contextualise the results of climate change experiments by comparison to other, naturally occurring stressors. The copepod starvation response involves the up-regulation of protein and lipid metabolism, with central roles for a novel class of taurine-containing lipids and the essential polyunsaturated fatty acids (PUFAs), eicosapentaenoic acid and docosahexaenoic acid. Copepods derive these PUFAs by ingesting diatoms and flagellated microplankton respectively. Climate-driven changes in the productivity, phenology and composition of microplankton communities, and hence the availability of these fatty acids, therefore have the potential to influence the ability of copepods to survive starvation and other environmental stressors.

S8 Oral Presentations, Day 3

March 27

March 27, 11:20 (S8-9923)

Global patterns of Tunas and Billfishes (marlins): Present and future

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Climate change scenarios have predicted an average sea surface temperature (SST) rise of 1–6ºC by 2100 and marine species are expected to respond to this warming by shifting their latitudinal range and depth. Studies on climate change impacts on marine biota are scarce at a global scale. Species distribution models (SDM) have been broadly used to access the impacts of climate change on biodiversity patterns. In this study, we explore the potential impact of climate change on the global patterns of Tunas and Billfishes. Using an ensemble forecast approach, we applied 10 different SDM's to project the potential distribution of 35 species by 2050 and 2100, under the Intergovernmental Panel for Climate Change (IPPC) A2 scenario implemented with the global model IPSL. We then aggregated geographically the species-level projections to analyze the projected changes in species richness and composition. We also investigated the change in body-size distributions at grid-cell scale for present-day and future time periods and linked it with the trends in landings since 1950. Finally we discuss the ecosystem impacts potentially induced by climatic change during this century and possible economic implications of such impacts.

March 27, 11:40 (S8-9971)

Beta, alpha and gamma benthic diversity on estuaries: What to expect?

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The description of major patterns of diversity is important in order to understand changes in community composition and/or richness at different spatial and temporal scales. Human impacts have pushed many estuarine systems far from their historical baseline of rich, diverse, and productive ecosystems. Despite the ecological and social importance of estuaries, there have not yet been many attempts to investigate patterns of beta, alfa and gamma diversity along estuarine systems of different spatial and temporal scales. We aimed to evaluate if benthic assemblages would show higher turnover than nestedness in tropical than in temperate systems, if well-known impacted estuaries would show greater nestedness than less polluted systems, and to propose a conceptual framework for studying benthic macrofauna beta diversity along estuaries. We analyzed benthic macrofaunal data from estuaries in different countries. We estimated alpha, beta and gamma diversity for each sampling time in each system and investigated patterns of beta diversity partitioning (nestedness and replacement). There was a decrease in alfa diversity along marine to freshwater conditions at most of the estuaries and sampling dates. Most

of the estuaries showed a greater proportion of beta diversity driven by replacement than nestedness. We suggest a conceptual framework for understanding diversity in estuaries and discuss what to expect in a future with climate change.

March 27, 12:00 (S8-9975)

Understanding marine regime shifts: Detecting possible changes in structures and functions in coastal and pelagic food webs

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Anthropogenic drivers, such as climate change and fishing, have severe, often unexpected impacts on marine ecosystems. Species responses to perturbation may have cascading effects through food webs, potentially altering ecosystem structure and functioning. This study deepens the understanding of marine regime shifts by investigating whether changes in ecological functioning co-occur with structural marine regime shifts. Food web reorganizations have been documented in several marine regions, *e.g.* in the Baltic Sea. We applied Exponential Random Graph Modelling (ERGM) and motif theory on the Baltic Sea food webs before and after the reported regime shift to identify altered structure and ecological processes as captured by changes in motif prevalence. To authors' knowledge this is the first study where ERGM tool is applied on food webs.

The results from comparing the minimal set of motifs generating the Baltic Sea food web models reveal that the coastal region has experienced changes in the dominant ecological functioning. For the offshore region the main ecological processes have remained the same despite the general regime shift. Our study indicates the role of the coastal zone as the interface ecosystem between land and sea, and discusses potentially increased vulnerability to functional change in the offshore Baltic Sea. The performed analyses extends the research on the Baltic Sea regime shift to detecting specific changes in ecological processes, and serves as a demonstration of a novel tool for detecting and examining changes in ecological processes within species assemblages.

March 27, 12:20 (S8-9978)

Macroecological patterns of trophic structure and community stability in marine ecosystems

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The relative strength and importance of consumer versus resource control within and across marine ecosystems has been intensively investigated for over a century. This research has led to numerous interesting discoveries, yet a unified explanation for spatial and temporal differences in trophic control and the factors influencing these patterns at macro-ecological scales remain elusive. The impacts of changing environmental conditions, exploitation, and trophic structure on community stability is also unexplored. Here, we use published field studies and fishery-independent scientific survey data to quantitatively examine patterns of trophic control and community stability within and across marine ecosystems. The type and strength of trophic control was assessed using a time-variable statistical indicator, which was estimated from time-series of predators and their prey. Our analysis integrates over 700 individual time-series compiled from over 60 studies published since 1950 among species ranging from phytoplankton to whales. Multivariate spatial regression analysis will be used to quantitatively test the effect of several biotic and abiotic factors influencing spatial and temporal patterns of trophic control. Finally, the relationship between the type and strength of trophic control and the stability of the ecosystem will be explored

using a community matrix approach. This method describes the temporal evolution of an ecosystem in the form of a linear dynamical system in order to estimate stability metrics such as the resilience, reactivity, and resistance to disturbance. Cumulatively, these results will yield new insights into the factors which underlie the trophic dynamics and stability in large marine ecosystems.

March 27, 14:00 (S8-10061)

Modelling Mediterranean Sea ecosystem state under contemporary and future climate

Cosimo **Solidoro**[1,2], Paolo Lazzari[1], Gianpiero Cossarini[1], Giovanni Galli[1], Donata Melaku Canu[1], Marcello Vichi[3], Tomas Lovato[3], Michele Scardi[4], Simonetta Fraschetti[5], Corinne Martin[6] and Marianna Giannoulaki[7]

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An ensemble of atmospheric, physical biogeochemical and ecological model has been used to assess the impact of future climatic and management scenarios on biogeochemical and ecological properties of the Mediterranean Sea. Results are discussed in terms of temporal and spatial distribution of parameters and indicators related to the carbonate system and the cycles of carbon and inorganic nutrients through dissolved and particulate phases, as simulated by a multi-nutrient multi-plankton numerical model under current and future climate conditions. Simulations span the period 1990-2040 and are performed by forcing a three-dimensional off-line coupled eco-hydrodynamic model (BFM and OPA-tracer model) with current fields produced by ad-hoc implementation of the NEMO modelling system and with river input of nutrient and freshwater computed in recent European FP7 projects (such as Perseus and MedSeA).

The model properly describes available experimental information on contemporary seasonal dynamic and spatial distribution at the basin and sub-basin scale of major biogeochemical parameters, as well as primary production and carbon fluxes at the air-ocean interface. Model projections suggest that future Mediterranean Sea will be as a whole warmer, more productive, and more acidic, but with significant space variability. These projections are then used to drive habitat suitability models for biogenic habitats (Posidonia oceanica seagrass, coralligenous formations, maerl beds) as well as to evaluate impact of changes in extreme event dynamics (heat waves) on selected species of ecological or economical values (red coral, calms, mussels).

March 27, 14:20 (S8-10067)

Future global patterns of marine cleaning interactions

José R. **Paula**[1,2], Joana Boavida-Portugal[1,2,3], Alexandra S. Grutter[4], Miguel B. Araújo[3,5] and Rui Rosa[1,2]

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Cleaning mutualisms are key ecological components in marine ecosystems and drivers of biodiversity and abundance. Nonetheless, until now, there is no knowledge on present and future climate change-driven changes in the global patterns of fish cleaning interactions. Cleaner organisms remove ectoparasites from their so-called "clients" (usually larger reef fish) in complex and cognitive demanding cooperative interactions that could involve tactile stimulation and partner control. Climate change scenarios have predicted an average sea surface temperature (SST) rise of 1–6ºC by 2100 and marine species are expected to respond to this warming by shifting their latitudinal range and depth. Using an ensemble forecast approach, we applied 10 different species distribution models to project the potential distribution of 91 cleaner fishes by 2050 and 2100, under the Intergovernmental Panel for Climate Change (IPPC) A2 scenario implemented with the global model IPSL. We also investigated how cleaning dependency (facultative vs obligate cleaners) change at grid-cell scale for present-day and future time periods. The related jeopardies for marine ecosystem's heath and functioning are also discussed.

March 27, 14:40 (S8-10126)

Diversity of blood-oxygen binding traits in the global ocean

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Large regions of the pelagic ocean are hypoxic between depths of 150 m and 1000 m. Recent observations indicate that deoxygenated waters are shoaling and compressing the thickness of the vertical habitat of overlying marine ecosystems. Marine organisms ranging in size from tiny zooplankton to large predatory fish utilize the vertical habitat to forage for food and avoid predators. One adaptation that determines the tolerance of organisms to hypoxic conditions is the oxygen affinity of oxygen-transport proteins, hemoglobin and hemocyanin. Oxygen affinity is quantified relative to the oxygen tension at which hemoglobin/hemocyanin is 50% oxygenated, which is referred to as P_{50}. Temperature is an additional environmental factor that needs to be considered because oxygen affinity is sensitive to temperature for many species. P_{50} is adjusted for the effect of temperature by using the heat of oxygenation. P_{50} depth is the depth in the ocean water column at which the oxygen tension equals P_{50}. We determine the global distribution of P_{50} depths for a range of oxygen affinities and heat of oxygenation values. Heat of oxygenation has an effect on the vertical position and areal extent of P_{50} depths. The vertical distance between P_{50} depths was regionally variable - in some areas P_{50} depths were similar while in other areas P_{50} depths were separated by >100 m. Based on these results, we predict that habitat compression will alter species interactions in regions where vertical distances between P_{50} depths are increasing or decreasing.

S9 Oral Presentations March 27
Impact of climate change on ecosystem carrying capacity via food-web spatial relocations

March 27, 11:20 (S9-9960), Invited

Moving parts of the food web: Detecting and predicting climate-induced migratory changes to structure, function, resilience and production of marine ecosystems

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We have documented evidence that many marine taxa are moving in response to climate change. There are many caveats to these movements, but typically this is a shift to waters that maintain preferred thermal habitats, with the sum result that species move into and out of ecosystems. Although we see these documented shifts in distribution, phenology, migration, and similar movements, what are their indirect and higher order effects? Both invasive and exodus species have implications for marine ecosystems. Here I explore the food web effects of such shifts. Using the analogy of a hut, I explore how the size, shape and charm of the hut changes as various materials are either removed or added. What happens when more logs are added at the basal or side walls of the hut? What happens when more twigs are added to the roof of the hut? What happens when items are cleared from inside the hut? Conversely, what happens when portions of the walls or roof are removed? What happens when more items are placed inside of the hut? I present empirical and modeling results from when species at low, middle and upper trophic levels invade an ecosystem. I do likewise for when species leave an ecosystem. I also explore when both occur simultaneously. A key point is that the initial conditions, type, maintenance, and other, external pressures that act on the "hut" largely determine the specific outcome of adding or removing materials. Given these caveats, there are a few common outcomes for marine ecosystems when species are added or removed, such that opportunities, and warnings, can be generally expected.

March 27, 11:50 (S9-10012)

Evaluation of potential trophic impacts from hake (*Merluccius merluccius*) emergence in the North Sea

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During the last fifteen years, northern European hake (*Merluccius merluccius*) abundance has increased to reach historically high spawning stock biomass in 2011. In the same period, the distribution area of northern hake has changed, particularly in the North Sea, where hake probability of occurrence increased along with a considerable expansion of this species probable habitat. The spatial shift of this top-predator fish, correlated with temperature as highlighted in a previous study, might impact local trophic interactions in direct and indirect ways. Potential direct impacts concern, for example, forage fishes stocks through new predator-prey interactions, while potential indirect impacts concern other predators, like North Sea saithe (*Pollachius virens*) trough potential competition. In this context, we quantified hake diet in the North Sea from stomach samples. Hake diet and abundance data were included in the most recent ICES key-run for multispecies stock assessment for the North Sea (SMS model) in order to estimate hake induced predation mortality particularly regarding its main prey, *i.e*. Norway pout (*Trisopterus esmarkii*). This study was completed by an evaluation of hake emergence indirect effects on potential competitors' life history traits, particularly regarding North Sea saithe growth. An innovative approach using the key-run outputs and coefficients of correlation between Norway pout abundance and saithe growth was used in order to quantify these effects. Different scenarios were tested in order to predict, in a context of global warming, the range of potential changes in the food-web linkage of the North Sea due to hake emergence, particularly concerning the threesome composed by hake, saithe and Norway pout.

March 27, 12:10 (S9-10026)

Does body-size matter when marine systems face climate change?

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Body-size largely defines how organisms respond to changes in their environment. It can enable an organism to escape unfavorable conditions, or set limits for metabolic rates. In species interactions, body-size is a key factor in determining whether an organism exits an encounter as a predator, or a "bagged meal". Climate and body-size are closely linked in marine ecosystems. Climate affects individual body-sizes and body-size distributions within an ecosystem. Thus, climate may alter food web dynamics and ecosystem responses to future climate variation. In this contribution, we study the body-size distributions of commercially important fish and their prey in the Baltic Sea (North Europe) in two time periods (mid-1980s and early 1990s) with distinctly different climate conditions. The data shows changes in fish sizes, along with their spawning stock biomasses and size distributions of available fish prey. Referring to the existing knowledge about optimal predator-prey body-size ratios, the results reveal potential mismatches between the optimum and available prey size distributions for Baltic fish. Particularly, the decline in benthos abundance may have decreased the availability of optimum-sized prey for young cod after late 1980s. We also introduce a new size-structured model applied for the Baltic Sea to address the question "How can organism size distribution affect marine ecosystem response to environmental change?" from the mechanistic theory perspective. Moreover, human intervention, fishing in particular, can strongly shape size distributions of marine organisms. Hence, including the links between body-size and ecosystem dynamics in future climate change projections can highly benefit marine ecosystem management.

March 27, 13:40 (S9-10182)

Krill worldwide: A comparison of hypoxia tolerances of euphausiid species from Atlantic, Pacific and Polar regions

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Modern Oxygen Minimum Zones (OMZs) are extensive and prevail in most of the world oceans. Anthropogenic and climate induced changes will cause OMZs to expand, while coastal hypoxia is assumed to increase in extent and severity. Particularly in Eastern Boundary Upwelling Ecosystems (EBUEs), such as the Humboldt and the Benguela upwelling system, extensive OMZs prevail. Animals living in these areas have to physiologically and/or behaviourally adapt to the low oxygen levels or will be excluded from these areas or at least their vertical distribution ranges will be limited. It is assumed that some areas may experience a shift from an abundant and diverse regime to one that is depleted and dominated by vertical migrators. Furthermore, temperature effects impact the hypoxia tolerance of animals negatively.

Euphausiids are known as pronounced diel vertical migrators, thus facing different levels of oxygen and temperature within 12 hours and are an important trophic link between primary producers and higher trophic levels throughout the world oceans. The critical oxygen pressure (P_{crit}) and the regulation index (RI), as a method to differentiate between oxygen conformity and regulation, were used to assess hypoxia tolerances of different species from different ecosystems. Furthermore, diel vertical migration behaviour was monitored in some species. We will present and compare hypoxia tolerances of different dominant euphausiids species, show how oxygen availability may affect their vertical migration behaviour and assess how future climate scenarios (warming waters and decreasing oxygen content) may alter horizontal and/or vertical distribution of these species.

March 27, 14:00 (S9-9839)

The predictive potential of ecological niche models for plankton in the North Atlantic

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While plankton is the foundation of the food-web in almost all marine ecosystems, they are also the group of organisms whose distribution is responding the fastest to climate change. Understanding how food-web structures will alter in the future therefore crucially requires a reliable estimate of the biogeographical changes of planktonic organisms. One popular way to produce such estimates is employing statistical ecological niche models (ENMs): however, tests of their predictive skill in the real-world are rare. Here we use observational data from the worlds' most extensive long-term plankton observation program, the Continuous Plankton Recorder, to investigate the reliability of predicted plankton distributional shifts. Three popular ENMs are fitted and evaluated for four dissimilar plankton species, each represented by over 200 000 presence/absence observations in the North Atlantic and adjacent seas, covering the years 1958 to 2012. We fit the models to decadal subsets of the available data, and then use them to project both forward and backward in time, and thereby assess their predictive skill. We find that there is a moderate drop in model performance when ENMs are extrapolated in time, while there are pronounced spatial variations in model performance. Most importantly, the edges of the distributions are typically poorly estimated, suggesting that projections of range shifts may not be reliable. The commonly used single-value model performance scores are insufficient to capture these spatiotemporal variations and may lead to overoptimistic conclusions about model skill. Using multiple approaches to predict relocations of marine species could lead to more robust results.

March 27, 14:20 (S9-10259)

Advancing tools to examine climate-driven changes in trophic coupling: Physiological-based modelling of early life stages of North Sea fishes

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Climate-driven changes have occurred world-wide in the abundance and distribution of populations/stocks of marine fish species that are heavily exploited. Coupling long-term, retrospective analyses and novel, 3-d biophysical, individual-based models (IBMs) shows great potential to reveal a 'cause and effect' understanding of observed changes in key marine fish species. IBMs allow an amalgamation of organismal-level physiological responses and climate-driven changes in marine habitats (from ocean physics to lower trophic level productivity) to better understand processes affecting marine fish recruitment. Case studies are provided for some of the most ecologically- and commercially-important pelagic and demersal fishes in the North Sea including European anchovy, Atlantic herring, European sprat and Atlantic cod. Special emphasis is given on how to incorporate changes in zooplankton distribution and productivity to better project indirect (trophodynamic) pathways of climate influence on these and other fishes. Opportunities and challenges are discussed regarding the ability of these physiological-based tools to capture climate-driven changes in the food web dynamics of shelf seas.

March 27, 14:40 (S9-10249)

Empirical evidence suggests that global warming may induce abrupt shifts in plankton communities and subsequent recruitment failure in fishes

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In a recently published book (Elsevier 2014) it was proposed that predator-prey synergism in the plankton community, defined as predator-prey relationships enhancing abundances of both predator and prey, is an important structuring mechanism in marine ecosystems. This predator-prey model predicts that gradual global warming has the potential to cause abrupt and persistent shifts in the plankton community, which are propagated to higher trophic levels by causing recruitment failure in fishes. Reduced abundances of planktivorous fishes will result in increased biomass of plankton and thus increased primary productivity. The latter is related to the fact that during most of the productive season recycling constitutes the main source of nutrients for algal growth (two copepods recycle twice as much nutrients as one copepod). There is substantial empirical evidence in support of this prediction. An annual beach seine survey along the south coast of Norway (since 1919) has revealed repeated incidents of abrupt and persistent recruitment collapses in gadoid fishes in relation to increasing primary productivity from eutrophication and increasing temperature. Comprehensive testing in the field using Atlantic cod as a model species, and direct indirect evidence from plankton communities suggest that these recruitment failures were caused by abrupt shifts in the plankton. Consequently, reduced fish abundances following temperature induces shifts in the plankton community may thus reinforce the negative impacts of global warming and possibly render the ecosystem shifts irreversible.

March 27, 15:00 (S9-9906)

Labrador Sea convection blows life to the northeastern Atlantic

Hjálmar **Hátún**[1,2], Katja Lohmann[2], Daniela Matei[2], Johan Jungclaus[2], Selma Pacariz[3], Sólveig. R. Ólafsdóttir[4], Jón Ólafsson[4] and Manfred Bersch[5]

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Deep convection in the Labrador and Irminger Seas inflate the cold and low-saline subpolar gyre, which is a rich nutrient and zooplankton source for its surrounding warmer waters of Atlantic origin. We show that northeastward shifts of the subpolar gyre limb in the Irminger Sea result in biologically productive periods in the waters southwest of Iceland – both oceanic and even on the shelf. The on-shelf zooplankton abundances show characteristic 'high-or-low' variability, which closely reflects the winter mixed layer depths in the northern Irminger Sea, and the oceanic abundances of the ecologically most important zooplankton species – *Calanus finmarchicus*. The sub-decadal biological production peaks are probably predictable by half a year (local winter convection to subsequent summer production), and the advective time-lag from the Labrador Sea might induce an even longer predictability potential (up to 1.5 years). A dramatic decline in silicate concentrations during the last 20 years might, however, reorganize this system fundamentally.

March 27, 15:20 (S9-9891)

A cascade of warming impacts brings bluefin tuna to Greenland waters

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Rising ocean temperatures are causing marine fish species to shift spatial distributions and ranges, and are altering predator-prey dynamics in food-webs. Most documented cases of species shifts so far involve relatively small species at lower trophic levels, and consider individual species in ecological isolation from others. Here we show that a large highly migratory top predator fish species has entered a high latitude sub-polar area beyond its usual range. Bluefin tuna, *Thunnus thynnus* Linnaeus 1758, were captured in waters east of Greenland (65°N) in August 2012 during exploratory fishing for Atlantic mackerel, *Scomber scombrus* Linnaeus 1758. The bluefin tuna were captured in a single net-haul in 9-11°C water together with 6 tonnes of mackerel, which is a preferred prey species and itself a new immigrant to the area. Regional temperatures in August 2012 were historically high and contributed to a warming trend since 1985, when temperatures began to rise. The presence of bluefin tuna in this region is likely due to a combination of warm temperatures that are physiologically more tolerable and immigration of an important prey species to the region. We conclude that a cascade of climate change impacts is restructuring the food web in east Greenland waters.

S10 Oral Presentations, Day 1 March 24
Forecasting climate change impacts on fish populations and fisheries

March 24, 11:20 (S10-10039), Invited

Climate change effects on fish and fisheries

Elvira **Poloczanska**

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Working Group II (Impacts, Adaptation, and Vulnerability) of the Fifth Assessment Report (AR5) of the Intergovernmental Panel for Climate Change presented an increased focus on the Ocean and a synthesis of information across broad Ocean regions. In this presentation, I will discuss the evidence in AR5 at both global and local scales and the risks for marine ecosystems and associated fisheries. AR5 showed that observed impacts of climate change in the Ocean are already widespread. Sea surface temperatures of the ocean basins all show recent warming with climate variability contributing to regional variations. Changes in oxygen content, pH, and ocean mixing have implications for nutrient and carbon cycling, ocean productivity, marine habitats, and ecosystem structure. Considerable variability in responses within and among species groups, these differences suggest species' interactions and marine ecosystem functions may be substantially reorganized at the regional scale. Climate change is a risk food resources, coastal livelihoods, and industries dependent on the Ocean, adding to the threats of over-fishing and other non-climate stressors. Adaptation to these changes may be possible in the short-term through dynamic fisheries policy and management (*i.e.*, relocation of fishing effort). However, the capacity for adaptation and strategies to reduce vulnerability will vary among industries.

March 24, 11:50 (S10-10222)

Small pelagics and climate change

Joana **Boavida-Portugal**[1,2,3], José R. Paula[2,3], François Guilhaumon[4], Miguel B. Araújo[1,5] and Rui Rosa[2,3]

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Many of the highly productive mid-latitude marine ecosystems share a prominent aspect in the configuration of their biological community structures. They appear to have a 'wasp-waist' food web, whereby the bottom (planktonic trophic levels) and top (apex and near-apex levels) of the food chain have high species diversity, while the intermediate trophic levels are occupied only by few small pelagic fishes (SPF). Small pelagic fish population dynamics is strongly correlated with temperature fluctuations, and since average global sea surface temperatures are expected to increase up to 1-6ºC by 2100, this warming trend may dictate profound impacts on SPF distribution and abundance. In this study, we use species distribution modelling to explore the potential impact of climate change, namely temperature and primary productivity, on the global distribution of small pelagic fishes. Using an ensemble forecast approach, we applied 10 different SDM´s to project the potential distribution of 147 species of relevant SPF's by 2050 and 2100, under the Intergovernmental Panel for Climate Change (IPPC) A2 scenario implemented with the global model IPSL. We then aggregated geographically the species-level projections to analyze the projected changes in species composition. We also investigated the changes in body-size distributions at grid-cell scale for present-day and future time periods and linked it with the global trends in landings since 1950. Finally we discuss the ecological and economic impacts potentially induced by climatic change and consequences of possible regime-shifts observed between species.

March 24, 12:10 (S10-10050)

How might environmentally-driven changes in the distribution of arrowtooth flounder affect eastern Bering Sea walleye pollock predation mortality and population projections?

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Arrowtooth flounder (*Atheresthes* sp.) are an important predator of juvenile walleye pollock in the eastern Bering Sea shelf, and their avoidance of the summer "cold pool" (bottom water ≤ 2°C) has resulted in variability in their spatial distribution. Spatially-resolved predation mortality rates were estimated within the age-structured walleye pollock stock assessment population model, based upon spatial information on diet and abundance (from trawl surveys). Estimates of predation mortality attributed to arrowtooth flounder have increased due to the increase in arrowtooth flounder abundance. Empirical relationships between the extent of the eastern Bering Sea shelf summer "cold pool" and maximum sea ice extent and sea level pressure allow projections of cold pool area from global climate model simulations, and can be used to predict future spatial distributions of arrowtooth flounder and pollock. Projections of cold pool area to 2050 based upon 15 International Panel on Climate Change model runs show a wide range of variability but an overall decreasing trend, resulting in a projected increasing trend in the area occupied by arrowtooth flounder. The projected impact of arrowtooth flounder predation upon walleye pollock is expected to be small because the changes in spatial distributions largely affect areas with limited juvenile pollock abundance. However, increased predation would be expected if arrowtooth flounder shift their distribution northward. An age-structured population model will be used to evaluate how projections of pollock abundance and yield are affected by information on projected spatial distributions and predator-prey overlap.

March 24, 14:00 (S10-9918)

Potential climate impacts of ocean warming to squid inferred habitat in North Pacific: Implications on future resource availability

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Climate-driven changes in the marine ecosystems have been found to impact the distribution, abundance and consequently the availability of marine resources to fishery. In the present work, we examined the potential habitats of neon flying squid in response to projected regional ocean warming off the North Pacific, using the sea surface temperature (SST) projections from a suite of CMIP3 (SRESA1B) and CMIP5 (RCP4.5) climate models. Squid summer potential habitats were inferred using maximum entropy (MaxEnt) model, developed from an 11-year (May-July 2000-2010) summer fishing positions and environmental factors (SST, sea surface salinity, sea surface height and net primary productivity). Present-day squid habitats were projected from the median values of 11-year environmental data. The potential effects of future elevated SST on squid potential habitats for May-July 2025, 2050 and 2100 were deduced using respective SST climate model projections. The mean and median monthly habitat suitability index (HSI) projections across CMIP3 and CMIP5 models were subsequently computed, to examine future HSI changes. Projected spatial HSI distributions across suite of climate models for CMIP3 and CMIP5 showed both contraction and expansion patterns of squid potential habitats relative to present-day HSI in western and central North Pacific. Moreover, future HSI maps also revealed a northward HSI displacement in response to warmer and stratified ocean conditions that could limit sub-surface nutrient transport and hence, food availability. Insights on the spatio-temporal patterns and shifts in squid potential habitats could lend important implications on the future availability of squid resources to fishery.

March 24, 14:20 (S10-10027)

Future fish distributions constrained by depth in warming seas

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European continental shelf seas have experienced intense warming over the last 30 years. In the North Sea, fishes have been comprehensively monitored throughout this period and resulting data provide a unique record of changes in distribution and abundance in response to climate change. We use these data to demonstrate the remarkable power of models, trained on data earlier in the time-series, to reliably predict trends in distribution and abundance in later years. Using the model coupled with climate projections we predict future distributions of demersal (bottom-dwelling) fish species over the next 50 years will be strongly constrained by availability of habitat of suitable depth. This will lead to pronounced changes in community structure, species interactions and commercial fisheries, unless individual acclimation or population-level evolutionary adaptations enable fish to tolerate warmer conditions or move to previously uninhabitable locations.

March 24, 14:40 (S10-10190)

How do alternative models of individual growth affect size-structured population and community responses to climate change and fishing?

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Size structure affects the resilience of populations and communities to top-down and bottom-up perturbations (*e.g.* fishing and climate variability and change). The individual growth process is a core part of models that predict population and community abundance and size structure. Different hypotheses exist for how food, oxygen, and temperature limit growth. However, a comparison of how these different environmentally-dependent growth processes impact population and community dynamics has not been conducted. Here we present a size-based multispecies model built on physiological bioenergetics of an "average individual" including processes such as growth, reproduction and mortality. The model is parameterized using species-specific values for our chosen study site, the North Sea, though it can be parameterized to other ecosystems if data is available. We integrate contrasting alternative growth hypotheses that link temperature, oxygen and food availability into the model to test their relative effects on hind-casted and forecasted trajectories of abundance and size structure. Contrasting alternative growth hypotheses enables us to capture an important aspect of model uncertainty in past and future climate change impacts on fish communities.

March 24, 15:00 (S10-9827)

The effect of an extreme marine heat wave on invertebrate fisheries in Western Australia

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A marine heat wave in the summer 2010/11 was centered on the mid-west region of Western Australia, resulting in sea-surface temperatures 5°C above average. The heat wave was due to a strong Leeuwin Current (influenced by a strong La Niña) and an anomalously high heat flux from atmosphere into the ocean. This had a significant effect on seagrass/algae habitat, coral communities, with fish kills and range extension of tropical species. A 99% mortality of Roei abalone occurred in some areas and translocation and release of hatchery-reared abalone are being examined to aid its recovery. A major reduction in recruitment of saucer scallops and blue swimmer crabs occurred in Shark Bay and Abrolhos. The annual pre-recruit scallop survey (also monitoring crabs) proved valuable for managers and fishers in the early detection of poor abundance resulting in an early response not to fish in 2012. The poor scallop recruitment continued with above-average temperatures in the following two summers, resulting in a record-low spawning biomass. The heat wave had some positive and negative effects on the prawn stocks in Shark Bay and Exmouth Gulf with a positive effect in Shark Bay. However there is anecdotal evidence that the seagrass habitat in Exmouth has been negatively affected and caused poor recruitment. These case studies highlighted the value of long-term environmental data and reliable pre-recruit abundance for early management adaptation response as a result of an extreme environmental event that may be more likely under climate change.

March 24, 15:20 (S10-10232)

Linking climate variability to rockfish recruitment

Jean-Baptiste **Lecomte**, Jacquelynne R. King and Andrew M. Edwards

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Forecasting the impacts of climate change on fish populations first requires the identification of mechanisms linking physical processes to the dynamics in recruitment. This is often a difficult step to achieve, and is limited in either the reliance on proxy variables or the lack of considering all sources of uncertainty when investigating statistical relationships. To address these issues, we present a Bayesian modelling approach to identify the impacts of climate variability on the recruitment of a rockfish population (Pacific ocean perch, *Sebastes alutus*) located in the Queen Charlotte Sound ecosystem of British Columbia, Canada. In particular, we use the marginal posterior distribution of the recruitments history provided by an age-structured model used for the stock assessment of this population. Pacific basin-wide shifts in atmospheric forcing and oceanic variability are linked to meso-scale eddy activity associated with Queen Charlotte Sound and overall ecosystem productivity. We use a direct measure of meso-scale eddy activity to provide the physical mechanism linkage to Pacific Ocean perch recruitment which is based on direct estimates from age composition data. The proposed modelling approach is the first step in the construction of an ecosystem based management approach for this species. The eventual intent is to use a suite of ecosystem state indicators to provide resource managers with ecological information that they can use to select a harvest strategy associated with forecasted biomass. We can also use the model developed to build scenarios of Pacific Ocean perch recruitment given ocean model forecasted conditions under climate change.

March 24, 16:10 (S10-10263), Invited

Climate change influences on India's marine fisheries

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The Indian Sub continent with 8129 km stretch of coastal line with the Arabian Sea on the western side and the Bay of Bengal in the eastern side has a vibrant fishing industry. Spread across nine maritime states there are 3288 fishing villages where about 3.9 million fishermen reside. Through targeted surveys among 4700 fishers across the country, fishermen's perspective on climate change and how it has impacted their life was studied. Apart from this, the Vulnerability Index of maritime states were estimated by considering the demographic features, occupational information, infrastructure available in the coastal areas, environment related factors and fishery aspects. Five major impacts were identified and a ten-point action plan for reducing impact was elucidated. Details of these will be presented.

Analysis of Impact of climate on fish distribution and phenology have indicated (1) change in distribution and increase in biomass of Indian oil sardine *Sardinella longiceps* to latitudes north of 14ºN, (2) movement of mackerel Rastraliger kanagurtha into deeper cooler water and (3) shift in spawning season of *Nempiterous japonicas* and *N. mesoprion.*

In India there are about 25 different craft and gear combinations operating within the Indian EEZ. Estimates of carbon emissions from fishing industry have indicated that India's emission intensity (1.02 t CO_2/t of fish landed) is low by about 40% per tonne of live weight landed. To reduce the fossil fuel consumption, the country is now providing Potential Fishing Zone Advisories to fishermen.

Apart from the above, results of recent data analysis on influence of climate variables on fishery resources, climate models in changed scenarios, adaptation and mitigation measures, Indigenous traditional knowledge (ITK) of fishermen, schemes implemented by the Government for climate adaptation and reducing vulnerability, peoples participation in combating abiotic climate stress and impact of CC on fisher women will be presented.

March 24, 16:40 (S10-9824)

Modelling fish production in Bangladesh under environmental change and socio-economic scenarios

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The fisheries industry provides a crucial source of income and food for Bangladesh, and is second only to agriculture in the overall economy of the country. Fisheries accounts for 4.4% of Bangladesh GDP, 22.8% of agriculture sector and 2.5% of total export earnings. It also contributes 60% of the animal protein intake of Bangladeshis, and even more in populations near the coast, which have doubled since the 1980s and now stand at 16 million people. Inland capture fisheries contribute 1 Mt of fish catch, and marine capture fisheries an additional 0.6 Mt. The main captured species (in both inland and marine catches) is Hilsa shad (*Tenualosa ilisha*), which accounts for approximately 10.6% of the inland and marine catches. As part of the ESPA Deltas project, we are developing tools to project the long term productive capacity of Bangladesh marine fisheries, with particular interest in Hilsa shad. These tools are based on climate-driven ecosystem model projections of water properties and primary and secondary production of the Bay of Bengal, which are used to develop size-based and species-based projections of change in fish productivity in coming decades. Here we present the fish projections for two species, Hilsa Shad and Bombay Duck, and total fish potential production of the Bay of Bengal by size classes, for years 2000 to 2099. All the models runs and scenarios show decreases in potential catches. However, they also show that good fisheries management can mitigate climate impacts. Some steps towards fisheries management has started with limited success.

March 24, 17:00 (S10-9857)

What the world's longest fish size time-series can tell us about climate change, fishing, eutrophication and war: North Sea plaice, 1902 to now

Georg H. **Engelhard**, John K. Pinnegar and Ewan Hunter

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The impact of climate change on marine ecosystems is a long-term process, and its effects are confounded with those from fishing, eutrophication and other anthropogenic drivers. Here we present arguably the world's longest time-series on fish size distribution – North Sea plaice *Pleuronectes platessa* – collated from survey logbooks archived at Cefas (UK, 1902–present) and contemporary data from ICES (1966–present). Large plaice were still common in the early 1900s when intensive trawling commenced, but their numbers already dropped substantially before WWI. During the 1920s–1930s, fishing was intense, and a lack of large plaice caused major concern of overfishing. Fishing halted during WWII, allowing plaice to recover with many large, old fish at the close of the war. With recommencement of fishing, large fish again became scarcer in the 1950s. An unexpected prevalence of large plaice in the 1960s–1970s was likely related with eutrophication and beam trawling resulting in high polychaete prey availability, favouring faster growth. Smaller sizes again became more prevalent in the population from the 1980s; this may reflect climate change and fishing, but also reduced riverine input and less eutrophication. Stomach contents analysis confirms a long-term dietary shift, from bivalves to polychaete worms, and reflects a major reorganisation in North Sea benthos, originally dominated by slow-growing bivalves but currently by rapidly-reproducing, trawling-resistant polychaetes, echinoderms and crustaceans. This exceptional time-series provides a unique opportunity to disentangle the cumulative effects of fishing, eutrophication, prey availability and political events, on top of climate change.

March 24, 17:20 (S10-9873)

Effects of near-future climate change, fishing, and marine protection on a temperate, coastal ecosystem

Tyler D. **Eddy**[1], Christopher E. Cornwall[2], Laurent Bopp[3], Tilla Roy[4], Beth Fulton[5] and Heike K. Lotze[1]

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5 CSIRO Marine and Atmospheric Research, Hobart, Tasmania, Australia

Predictions about the impacts of climate change on marine primary production and low trophic levels derived from GCMs can be employed to drive ecosystem models to make predictions about higher trophic-level and ecosystem-level responses. This bottom-up driven approach quantifies the ecosystem effects of changing primary production as it passes through the food web. Studies have also investigated how different groups of marine organisms are predicted to respond to increasing acidity in the ocean. Generally, it has been found that calcareous organisms are more susceptible to increasing ocean acidity, such as the phytoplankton group, coccolithophores. However various aspects of an organisms' physiology may respond differently, as their production, consumption, and mortality may respond in different ways. For example, some groups of macroalgae are predicted to show increased production with increasing ocean acidification. Understanding how all of these impacts of differing directions and magnitudes for various groups of species will integrate at the ecosystem level is important to make predictions about ecosystem responses to perturbations such as climate change. Additionally, many marine ecosystems will not experience these impacts in isolation from other stressors, as impacts from fisheries exploitation that have shaped marine ecosystems will continue to affect them. This paper will present work about how the structure and function of a New Zealand ecosystem has changed throughout fishing exploitation, the predicted effects of individual and cumulative stressors: fishing, ocean acidification, and climate driven changes in primary production, and the potential for management tools such as marine reserves to mitigate these impacts.

March 24, 17:40 (S10-10228)

Predicting how climate variation affects the Bering Sea pollock trawl and Pacific cod longline fisheries

Alan **Haynie**[1] and Lisa Pfeiffer[2]

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How will changing climate impact commercial fisheries? The observed impacts of climate variation on the spatial distribution of Bering Sea fisheries are surprisingly different than the impacts on fish populations. In this talk, we integrate work that independently examined the impact of climate change on the Bering Sea pollock and Pacific cod catcher-processor fisheries. We examine how both fisheries have adjusted to variation in economic conditions, changes in abundance, and environmental conditions. For pollock, the mean location of winter fishing has varied little between warm and cold years, but there has been a northward shift in summer pollock biomass and fishing. However, contrary to the idea that this shift would be correlated directly with warming temperatures, this shift is contemporaneously correlated with the colder-than-average climate conditions in the latter part of the last decade. For Pacific cod, the mean location of fishing has not shifted significantly as a result of climate variation, but the duration and other elements of fishing trips have changed. Climate affects relative spatial catch-per-unit-effort (CPUE) in both fisheries by causing a cold pool (water less than 2°C that persists into the summer) that both species avoid. In the Pacific cod fishery, vessels make long-distance moves more often in warmer, low-CPUE years, leading to significantly higher fuel costs. We discuss how both fisheries are likely to be impacted by future warming.

S10 Oral Presentations, Day 2 March 26

March 26, 09:00 (S10-9988)

Change in global fisheries economics with climate change

Vicky W.Y. **Lam**, William W.L. Cheung and U. Rashid Sumaila

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Change in climate results in shifts in the distribution and potentially the catch of marine species. These range shifts not only cause changes in catches, but can also have great implications for the economics, food security and livelihoods of fishing communities, and eventually other sectors of a given economy. Here, we apply multiple species distribution modeling approaches that are driven by oceanographic changes simulated by Earth System Models (ESM) to project future changes in the distribution and maximum catch potential of exploited marine fishes and invertebrates under different scenarios of climate change. By using different socio-economic scenarios to simulate changes in global fish demand, we model changes in fishing prices, fishing costs and other economic parameters. Our results suggest that climate change would lead to reductions in global catches of fish and the total revenues derived there from in the 2050s, and that most of these reductions would be in developing countries. Global resource rents are also projected to be redistributed in the 2050s under climate change. Sustainable fisheries management, if effectively implemented, is expected to offset some of the expected economic impacts, but large reductions of these impacts would require significant decreases in greenhouse gas emissions. Thus, it is essential that the implementation of effective fisheries management measures are included in the process of planning and designing of climate change adaptation strategies for fisheries worldwide.

March 26, 09:20 (S10-9894)

Long-term trends in the biomass of commercial fish in the North Sea: The role of fishing impacts, predator-prey interactions and temperature change

Christopher **Lynam**[1], Pierre Helaouet[2], Christian Möllmann[3], Marcos Llope[4], Roddy Mavor[5], Georgia Bayliss-Brown[1] and Nils-Christian Stenseth[6,7]

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We develop a statistical model of the North Sea pelagic and demersal systems using time-series data on temperature, phytoplankton and zooplankton abundance, fish biomass and mortality and seabird breeding success. The model distinguishes between temperature and fisheries effects on ecosystem components and demonstrates key interactions between species. Plankton groups are strongly influenced by temperature. Changes in zooplankton abundances alter the biomass of their predators (sprat, herring, sandeel and haddock), with some negative feedback by sprat and sandeel, and cascade up to predatory saithe, whiting and seabirds. All fish species are negatively impacted by fishing impacts, but for whiting this occurred only through indirect fishing effects on sprat and sandeel prey. Sandeel and cod are also influenced by temperature directly in the model and declined to low levels during the 2000s as the sea warmed. Scenario testing indicates that if temperatures had not risen since the mid 1980s, sandeel, cod and herring would have benefited to the detriment of Norway pout, sprat, whiting and saithe. Nevertheless the general trajectory of the biomass of fish stocks would have been little changed due to the stabilising effect of fishing. The simulated breeding success of seabirds did respond to climate effects via the differing responses of sprat and sandeel, which were modulated by the levels of fishing mortality imposed. For commercial fish stocks in the North Sea, fishing mortality can be considered the greatest driver of change since the mid-1960s and has likely had a cascading effect on the breeding success of marine birds.

March 26, 09:40 (S10-9849)

Modelling impacts of climate change on fisheries in the southern Benguela system

Kelly **Ortega-Cisneros** and Kevern L. Cochrane

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The southern Benguela system supports a productive fisheries sector including several fishing communities that depend on these resources for their livelihoods. The southern Benguela has been recently identified as a hotspot of climate and social change because it is warming faster than 90 % of the ocean and experiencing social change. It is one of five hotspots included in the international GULLS (Global Learning for Local Solutions) project, of which this study forms a part. This study aims to explore the impacts of climate change and variability on the abundance and distribution of key species on the southern Benguela, and their implications for management of selected fisheries using the ABACuS model (Atlantis on the Benguela and Agulhas Current Systems). The effects of climate change will be simulated using a 100 year time series (1990-2090) of physico-chemical parameters derived from the NEMO – MEDUSA 2.0 models. The model allows simulation of the possible effects of temperature and salinity on the food web, including harvested species and their associated fisheries. The presentation will describe progress made to date in identifying the possible ecosystem effects of climate change on the southern Benguela, the most vulnerable fishery resources, and options for management strategies for the small pelagic fisheries in the context of climate change.

March 26, 10:00 (S10-9828)

Fisheries, low oxygen and climate change: Integrating physiological data with model projections

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Oxygen availability is a key factor that determines habitat suitability for marine fish. As a result of climate change, low oxygen conditions are predicted to occur more frequently and over a greater geographic extent in the oceans. Much research has already been conducted with regard to the effects of acute hypoxia on the physiology of marine species, but far less on long-term, chronic effects and especially concerning commercially important fish and shellfish. It is important to integrate experimental results with modelling techniques, and there are large amounts of physiological data which can be used. Here, we demonstrate how the results of low oxygen laboratory experiments can be used in models to predict the effects of climate-induced low oxygen on fisheries. The critical oxygen thresholds and aerobic scope of a number of European commercial fish species were overlayed with hindcast and projected future oxygen concentrations and temperatures in the North Sea and the north-east Atlantic. Alongside the habitat requirements at various life stages and times of year, this modelling technique can determine the habitat suitability of fish and the possible consequences for reproduction, growth, yield and fisheries catches up to 2100. These results demonstrate the usefulness of combining simple experimental results with models to improving our understanding of climate change on fisheries, regionally and globally.

March 26, 10:20 (S10-10250)

A framework for evaluating IPCC AR5 projected climate change impacts on Bering Sea (AK) fish and fisheries

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Climate change is a global issue affecting marine ecosystems and species that span multiple international boundaries. To address this challenge scientists have developed global climate and earth system models (CGM and ESM, respectively) to project future conditions. These models are being tested regionally and discussed globally. In several regions, CGM or ESM output has been used to force regional ocean circulation models with coupled nutrient, phytoplankton and zooplankton dynamics however the methods differ regionally and internationally. In preparation for the next IPCC assessment, scientists have initiated an international collaborative effort to provide quantitative estimates of the status and trends of commercial fish and fisheries worldwide by 2019. Of particular interest are models that extend regional models to include projections of climate impacts on the distribution and abundance of commercial fish and fisheries. A variety of different models could be employed ranging from minimally realistic single-species climate enhanced stock projection models with detailed treatment of process error, measurement error and model misspecification to whole ecosystem models with complex treatment of ecosystem interactions and only modest treatment of uncertainty. The proliferation of modelling improvements and global projections creates a dilemma for regional ocean modellers and fisheries scientists as the number of possible permutations that could be explored rapidly can become too large to manage. Identifying a reasonable range of representative futures (with sufficient contrast in scenarios) and biological models allows analysts to compare projections and report on the relationship between model complexity, efficiency, and the computational costs of increased ecological realism in models. This paper presents a proof-of-concept implementation of a Management Strategy Evaluation (MSE) framework for the eastern Bering Sea for evaluating the performance of resource management strategies under different climate change scenarios.

March 26, 11:10 (S10-9903)

Seasonal forecasting as a stepping stone to climate adaptation in marine fisheries and aquaculture

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The production of marine protein from fishing and aquaculture is influenced by environmental conditions. Ocean temperature, for example, can change the growth rate of cultured animals, or the distribution of wild stocks. In turn these impacts may require changes in fishing or farming practices. In addition to short-term environmental fluctuations, long-term climate-related trends are also resulting in new conditions, necessitating adjustment in fishing, farming and management approaches. Longer-term climate forecasts, however, are seen as less relevant by many in the seafood sector due to more immediate concerns. Seasonal forecasts provide insight into upcoming environmental conditions, and thus allow improved decision making. Forecasts based on dynamic ocean models are now possible and offer improved performance relative to statistical forecasts, particularly given baseline shifts in the environment due to climate change. Seasonal forecasting is being used in marine farming and fishing operations in Australia, including wild tuna and farmed salmon and prawns, to reduce uncertainty and manage business risks. Forecast variables include water temperature, rainfall and air temperature, and are considered useful up to approximately 4 months into the future, depending on the region and season of interest. Species-specific habitat forecasts can also be made by combining these environment forecasts with biological habitat preference data. Seasonal forecasts are useful when a range of options are available for implementation in response to the forecasts. The use of seasonal forecasts in supporting effective marine management may also represent a useful stepping stone to improved decision making and industry resilience at longer timescales.

March 26, 11:30 (S10-9922) CANCELLED

Forecasting climate change impacts on Northeast Arctic cod recruitment abundance and the experience with their application by the ICES AFWG and SGRF

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One of the most important practical and theoretical problems connected with study of marine ecosystems is prediction of recruitment values in commercial fish populations. One of the experiments on application of the ecosystem approach for prediction of Northeast Arctic (NEA) cod recruitment abundance was modeling with the use of data on physical and chemical status of environment (Titov, 1999; Titov, 2001). Titov (2005) developed models with 1 to 4 year prediction possibility, based on the oxygen saturation at bottom layers, air temperature, water temperature, ice coverage in the Barents Sea. The models, as well as several other models (*e.g.* Stiansen *et al*., 2005) have been compared by the ICES Arctic Fisheries working group (AFWG) and adopted for practical use. The ICES Study Group on Recruitment Forecasting (SGRF) gave a "best practice" for choosing recruitment models. The method, involving a weighted average of individual model predictions, was proposed. Thus at present, natural processes, influencing the dynamics of the marine ecosystem, are taken into consideration when predicting values of cod recruitment. This leads to increase in prediction accuracy of recruitment abundances of cod and, correspondingly, to decrease in error at prognostication of NEA cod population abundance and fisheries. Based on the experience gained by author during the development of prediction models, the paper discusses the physical and chemical processes in the Barents Sea ecosystem, which reflect the impact of climate change on cod population.

S10

March 26, 11:30 (S10-9927)

Assessing the future effects of climate change trends on U.S. west coast sablefish productivity and on the performance of alternative management strategies

Melissa A. **Haltuch**[1], Z. Teresa A'mar[2], Nicholas A. Bond[3] and Juan L. Valero[4]

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The U.S. west coast sablefish fishery is a valuable commercially targeted species, making assessing and understanding the interaction between climate change and fishing a priority for (1) forecasting future stock productivity and (2) for testing the robustness management strategies to climate variability and change. The horizontal-advection bottom-up forcing paradigm describes large-scale climate forcing that drives regional changes in alongshore and cross-shelf ocean transport, directly impacting the transport of nutrients, mass, and organisms. This concept provides a mechanistic framework through which climate variability and change alter sea surface height (SSH), zooplankton community structure, and sablefish recruitment, all of which are regionally correlated. This study assesses future trends in sablefish productivity as well as the robustness of harvest control rules to climate driven changes in recruitment by conducting a management strategy evaluation of the currently implemented harvest control rule as well as an alternative. We use 50 year ensemble forecasts of sablefish productivity under a suite of future climate variability and change scenarios. Future recruitments are generated under two scenarios (1) the fit of a Beverton-Holt stock-recruitment curve based on historical data and (2) recruitments driven by a SSH-recruitment relationship that is treated as an age-0 survey of abundance with associated uncertainty. Multi-decadal forecasts of sablefish productivity could provide long term strategic advice to allow fishers and managers to plan for and respond to shifts in productivity.

March 26, 11:50 (S10-10010)

Temporal variability of upwelling parameters in the Zamboanga Peninsula, Philippines and its relationship with sardine production

Josephine Dianne **Deauna**[1], Olivia Cabrera[1], Patrick Pata[1], Cesar L. Villanoy[1], Roselle Borja[1], Laura David[1] and Asuncion de Guzman[2]

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The Zamboanga Peninsula is a major upwelling site in the Philippines, supporting a large small–pelagic fishery dominated by sardines. Coastal upwelling occurs during the NE monsoon when winds blow along the coast in a favorable orientation, while the shape of the coastline and its orographic features induces curl–driven upwelling. This work explores the long–term variability of upwelling in the area and their relationship with sardine catch. MODIS chlorophyll *a*, MODIS SST and TRMM rainfall values were computed for the area from July 2002 to July 2014. During El Niño periods, SST and rainfall decreased which reduces stratification and encourages upwelling. Consequently, MODIS chlorophyll *a* values had positive anomalies. Increased sardine fishery production was also observed during El Niño periods, albeit inconsistently. Future trends in the sardine fishery may be deduced by comparison with ENSO scenarios as predicted by climate projection models.

March 26, 12:10 (S10-10221)

Quantitative tools for predicting fish population dynamics and evaluating alternative harvest strategies under climate change for marine fisheries in Alaska

Carey R. **McGilliard**[1], André E. Punt[2], Jim Ianelli[1] and Grant Thompson[1]

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Recruitment and other population processes of groundfish in the Gulf of Alaska (GOA) and Bering Sea-Aleutian Islands (BSAI) have well-documented linkages to indices of environmental forcing and variability, such as the Pacific Decadal Oscillation (PDO), sea surface temperature and height, and sea ice extent. Quantifying scientific uncertainty due to future climate conditions and identifying management strategies that are most robust to climate uncertainty are therefore key parts of providing scientific advice to fisheries managers in these regions. Management Strategy Evaluation (MSE) is a powerful simulation tool for such explorations. In an MSE, fish population dynamics, and the process of harvesting, sampling fish populations, assessing the status of fish populations, and specifying and implementing assessment-based management, is simulated over a number of years. Linkages between fish population dynamics and environmental variables can be incorporated into MSEs. An MSE was developed with application to Alaska groundfish species to examine the performance of an alternative management strategy that quantifies scientific uncertainty, including uncertainty about future climate conditions, and incorporates estimates of the magnitude of uncertainty into harvest regulations. Results were compared to long-term outcomes of continuing to use the current harvest regulations. The probability of extinction or the probability of the population falling below a biomass threshold, long-term catch, and variability in catch were calculated. Future research will expand the population dynamics in the analyses to include multiple species, linked through technical interactions.

S11 Oral Presentations March 25
Impacts on coastal communities

March 25, 11:20 (S11-9939), Invited

Climate change vulnerability and adaptation in the low-lying tropics: The case of shrimp farming in coastal Bangladesh

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The coastal aquaculture sector in Bangladesh is dominated by export-oriented brackish water shrimp (*Penaeus monodon*) farming which was initiated in the 1970s as part of agricultural development. Over the last three decades, shrimp culture has undergone a revolutionary development in coastal Bangladesh. The practice of shrimp farming is widespread in coastal Bangladesh, because of the availability of wild postlarvae, favorable agro-climatic conditions, and suitable biophysical resources. The rapid expansion of this sector has emerged as a means of accelerating economic growth. Shrimp farming in coastal Bangladesh plays an important role in the economy of the country, earning valuable foreign exchange, contributing to increase food production, diversifying the economy, and increasing livelihood opportunities. In recent years, however, climate change has been identified to threaten the sustainability of shrimp farming. Bangladesh is subject to climate extremes and prone to natural hazards as the country is located close to the Great Himalayan Ranges in the north and Bay of Bengal in the south. Different climatic variables including flood, drought, rainfall, cyclone, sea-level rise, salinity, and sea surface temperature have had adverse effects on shrimp production as well as socioeconomic conditions of farming households. Adaptation strategies in coping with the impacts of climate change on shrimp farming must be developed. Considering extreme vulnerability to the effects of climate change on shrimp farming, community based adaptation strategies need to be introduced to cope with the challenges. Effective planning in respect to coastal zone management would also be given particular attention.

March 25, 11:50 (S11-9962)

Analyzing climate change impacts through social wellbeing lens: The case of Bangladesh coastal community

Mohammad Mahmudul **Islam**

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Using social wellbeing approach as analytical lens, this study investigates how climate change induced events affect social and cultural values of the communities living in the coast of Bangladesh. Qualitative methods were employed to collect data from three coastal communities and matrix was assigned to quantify negative impacts on the subjective, objective and relational well-being values of various professional groups such as fishers, farmers and the wider coastal communities of Bangladesh. Through considerations of these values, multifaceted vulnerabilities of the communities were assessed and implications on their wellbeing were drawn. Given that, in Bangladesh concerns about social wellbeing are met by a dearth of research and received much neglected focus in climate change adaptation research the findings could prove important in learning of psychological and behavioral response to climate change impacts. Understandings about how climate change impacts, for example affect the quality of life, identity and connections to place where people live, will help to effectively disentangle the human dimension of climate change impacts and adaptations, that will in turn help to identify appropriate policy responses to make climate resilient coastal communities in Bangladesh.

March 25, 12:10 (S11-9816)

Climate change and vulnerable communities: A study on coastal fisheries from India

Sibananda **Senapati**

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This study use sustainable livelihood approach as well as analytical hierarchical process for understanding the vulnerability of indigenous fishing communities known as 'Koli' living in coastal plain of Mumbai, India. In this study various aspects of vulnerability (sensitivity, exposure and adaptive capacity) are analyzed with the help of indicators drawn from sustainable livelihood approach and a primary survey comprising two hundred fishermen families from five fishing villages in Mumbai. Results show households possess different levels of vulnerability depending upon their possession of livelihood assets and their occupation. Households depending mostly on full time fishing and small scale non-motorized fishermen are more vulnerable compare to others. Fishermen having motorized fishing boats and those who use modern fishing techniques could adapt efficiently to climate change and their productivity has increased. Although the adaptation techniques adopted by these fishermen are mostly confined to improve their livelihood and not very specific to climate change. Various such adaptation techniques of fishermen are discussed in this study. We suggest that the government need to take actions for improving the livelihood like; providing better financial facility, and training for catching the type of fish now available due to change in climate.

March 25, 14:00 (S11-10141)

Transforming fisheries management to build climate-resilience in seafood security of coastal countries

William W.L. **Cheung**[1], Vicky W.Y. Lam[1], Miranda C. Jones[1], Dana Miller[2] and U. Rashid Sumaila[2]

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Seafood is an important source of livelihood and nutrition to many people, in particular, those in coastal communities. However, climate change (CC) and ocean acidification (OA) are projected to redistribute fisheries biomass and therefore catches, with many tropical regions suffering decreases in seafood production that threaten food security of coastal communities. Building climate-resilience for these communities requires transformations at multiple levels. This study uses simulation modelling to examine the potential co-benefits of transforming international fisheries governance in reducing the vulnerability of coastal countries in the world to CC and OA in terms of their food security. Specifically, we use high seas fisheries closure, recently being suggested as a way to increase catch and revenues to many coastal states, as a case study. Under multiple scenarios of CC and OA, and fisheries and socio-economic development pathways, we project the degree to which closing the high seas could reduce vulnerability of coastal states to seafood insecurity by 2050. We then examine the challenges and opportunities of transforming international fisheries governance such as high sea fishing closure to build climate-resilience for food security of coastal communities.

March 25, 14:20 (S11-9973)

Fishers adapting to change: A cascade of climate, environment, management, economic and social changes

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One of Australia's iconic fishing communities, the rock lobster fishers of the Abrolhos islands, has experienced significant change over the past years. A cascade of climate and environmental changes, management responses and economic influences has led to social decline and community collapse on some of these low-lying islands off the coast of Western Australia. In WA from 2006 there has been a very low rate of settlement of post-larval rock lobsters, which appears to be climate driven. To protect the stocks, managers imposed significant catch and effort reductions across the entire fishery. These management changes resulted in almost half of the boats leaving the fishery. A different style of management was also introduced and the fishing season was extended which changed the way people fished. Many fishers have exited the industry, making the decision to sell or lease their licences. The fishers who remained in the fishery have adapted by: buying units from other fishers; altering their pattern of fishing so that they fish to price; coming to the Islands only when the price is high; supplementing their income with alternative livelihoods. As a result there are now few people on the islands at any one time; all schools, clubs and sporting events have shut down. We investigated linkages among climatic, environmental, management, economic and social changes and communicated these back to the broader community using the fisher's own photographs to tell their story. The resultant photographic exhibition and book about the fishers' experiences and adaptation strategies won multiple awards.

March 25, 14:40 (S11-10129)

Social vulnerability of coastal communities to climate change: A Southern hemisphere comparison

James A.E. **Howard**[1], Shankar Aswani[2], Mary Gasalla[3], Sarah Jennings[4], Willem Malherbe[2], Ivan Martins[3], R. Narayanakuma[5], Shyam S. Salim[5], P.S. Swathilekshmi[5] and Ingrid van Putten[6]

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Marine dependent fishing communities worldwide face a growing multitude of threats and pressures which affect their livelihoods, cultures, food security and resource base. Furthermore, climate change impacts are projected to compound existing stressors and increase the vulnerability of such communities. This paper presents a comparison of social vulnerability assessments conducted in regions of five countries (Brazil, South Africa, Madagascar, India and Australia) which border some of the fastest warming ocean areas in the southern hemisphere. This work represents the first stage of an ongoing, interdisciplinary, international Belmont Forum project known as GULLS (Global Understanding and Learning for Local Solutions) aimed at understanding and reducing vulnerability of coastal communities. Each country team conducted household surveys with marine dependent communities, utilising a novel framework which expanded and moved beyond the standard three dimensions of vulnerability to climate change: exposure, sensitivity and adaptive capacity. In particular, this vulnerability assessment was designed to maximise the potential for robust cross-cultural comparison and takes into account the many critiques of vulnerability assessments made to date. In addition to presenting our preliminary findings and analysis of survey data, this paper will also discuss the process of our cross-cultural methodology and reflect on the strengths of pairing detailed local scale work with regional scale comparison in seeking potential solutions to reducing vulnerability.

March 25, 15:00 (S11-10099)

Climate change impacts on coastal societies and infrastructure – Assessing risk against a changing population in the north coast of São Paulo, Brazil

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The risks from climate change in the coastal zone are large, increasing, and in some areas will be felt in the near term. In countries such as Brazil, the favelas, settlements mostly populated by disadvantaged populations and largely situated along mountainsides, experience greater vulnerability to natural disasters and other urban environmental risks. Nevertheless, despite the recognized importance on the topic, climate change and its related impacts are not well understood or taking into consideration at local and regional planning scales. At the local scale there are pressures related to settlement for construction and operational assets associated with ports expansion and mega-development infrastructure of the oil and gas industry. From the state and federal side, there are political and economic pressures imposed by mega-projects development associated with the Pre-Salt exploration offshore which does not consider local management needs and priorities on land use planning. In this talk, we will present the major findings of the RedeLitoral, a multidisciplinary project that aimed to promote the consolidation and update of knowledge about climate change impacts and its effects on society, built infrastructure and land use planning in the north coast of São Paulo. Findings indicate that human settlement, mainly driven by tourism and mega-industrial developments, has induced urban sprawl towards the most vulnerable areas making such places more susceptible to climate change impacts. Fragmented and sectored licensing processes are not considering the cumulative and synergistic environmental effects resulting in inadequate public policies.

March 25, 15:20 (S11-10188)

Considerations on the potential of increase in coastal vulnerability in Tinharé and Boipeba Islands, Bahia, Brazil, in face of climate change

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Coral reefs can attenuate offshore wave energy, providing sheltered waters and protecting coastlines. Yet, in face of climate change and chronic impacts, this and other ecosystem services may be impaired. The fringing coral reefs of Tinharé and Boipeba islands, Brazil, provide important ecosystem services. To assess the potential coastline protection provided by these coral reefs, the InVEST coastal vulnerability (CV) model was applied in two scenarios: 1) Current CV analysis, 2) Predicted CV in the absence of coral reefs. In the current scenario 34.1% of the coastline was classified as moderate to high vulnerability. In the absence of the coral reefs, moderate to high vulnerability reached 46.8% of the coastline, and considering all areas that presented any increase in vulnerability rate, 50.5% of the coastline was affected. These results are especially concerning given the potentially lower resistance these coral reefs present to climate change, due to chronic human impacts. Local coastal communities are thus subjected to a significant loss in well-being given the potential increase of erosion, which could lead to a decrease in tourism activities, the main revenue of the area. Positive thermal anomalies, ocean acidification and sea level rise pose important threats and can act as tipping points for coral decline in the region, leading to increases in CV along most of the coastline. Management strategies should include climate change adaptation and ways of tackling these local stressors, thus providing greater resilience and possibly allowing natural adaptation to oncoming conditions, avoiding such a loss in ecosystem service provision.

March 25, 16:10 (S11-9808)

Anthropogenic and climate effects on change of marine ecological capital

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Marine ecological capital (MEC) concept is developed based on the natural capital and ecosystem service theories. MEC is those marine ecological resources which provide benefits for mankind. It consists of marine living organisms and their habitat and the whole marine ecosystem. The value of MEC includes not only the value of standing stock of marine ecological resources but also the value of marine ecosystem services. According to the Guidelines for Marine Ecological Capital of China, the ecological capital was evaluated in the coastal waters of Shandong province, China. In its approximately 31,600 km² of coastal waters, this coastal ecosystem had CNY173.74 billion of ecological capital including CNY19.41 billion of standing stock of marine living resources and CNY154.33 billion of ecosystem services in 2008. In total ecosystem services, the value of cultural services was CNY90.48 billion and accounted 58.6% of total, the value of provisioning services was CNY57.41 billion and accounted 37.2%, the value of supporting services was CNY41.0 and accounted 2.7%, the value of regulating services was CNY2.35 billion and accounted 1.5%. The cultural and provisioning services are major services provided by marine ecosystem. Ecosystem service value decreases gradually from onshore to offshore waters. More service value provided in maricultural and recreational areas than the other waters. The spatial pattern highly depends on the manner and pattern of sea use. The service value of the same above waters was evaluated in 2013 again. The total service value did not show big difference. However the obvious differences in both spatial pattern of service and the ratios between services were detected. The causes from human activities and climate change were identified. The recommendations were submitted to local Ocean and Fisheries Department.

March 25, 16:30 (S11-10073)

Evaluation of climate change impacts on the sea-turtle nesting beaches of Zakynthos National Marine Park, Greece

Fotis Psarros[1], Isavela Monioudi[1], Olympos Andreadis[1], Thomas Hasiotis[1], Adonis **Velegrakis**[1], Antonis Hatzipavlis[1], Vasilis Trygonis[1] and Charalambos Dimitriadis[2]

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A widely projected impact of the changing climate is sea level rise (SLR), which will likely result in more extensive inundation of low-lying coastal areas and increased coastal erosion. The aim of this contribution is the predictions of the potential retreat of the five *Caretta caretta* nesting beaches in the National Marine Park of Zakynthos (Laganas Gulf) under different SLR rates using six beach analytical and numerical 1-D morphodynamic models of different complexity, methodologies not so far been used to other nesting beaches worldwide. The main inputs for the application of the models were topographic, bathymetric, sedimentological, meteorological data and four different SLR scenarios (0.2, 0.5, 1.0 and 2.0m). Results show that SLR institute a major sea-turtle threat since it will result in significant beach changes and retreats/inundations, which compared with the present beach spatial characteristics (10-50m width) demonstrate highly critical impacts on the sea turtle nesting beaches. For example, our projections suggest that SLR of 1m will induce beach width losses more than 50% of their present width, whereas a 2m SLR (extreme events) will likely be devastating, since all five beaches will be entirely inundated. As these beaches constitute a vital component of the E. Mediterranean sea-turtle ecosystem, systematic annual nesting surveys and environmental parameters (beach/slope changes, compaction and moisture levels, sand temperature *etc.*) monitoring could provide a valuable input to GIS-based models, so as to evaluate and quantify the effect of coastal squeeze on nesting activity in the case of various SLR scenarios.

March 25, 16:50 (S11-9995)

A marine climate change adaptation blueprint for coastal regional communities

Ingrid **van Putten**[1,2], Sarah J. Metcalf[3], Stewart Frusher[1], Nadine A. Marshall[4], Malcolm Tull[3], Nick Caputi[5], Marcus Haward[1], Alistair J. Hobday[2], Neil Holbrook[1], Sarah Jennings[6], Gretta Pecl[2] and Jenny Shaw[7]

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A marine climate adaptation blueprint aimed at assisting coastal communities to develop adaptation plans was developed for Australia. The project utilised an innovative approach combining qualitative and semi-quantitative methods based on existing demographic data, expert knowledge, and semi-structured interviews. A boundary organisation (Oceanwatch) was used to ensure that key community and industry participants were engaged and relevant linkages between climate and non-climate pressures were identified. The methodology that underpins the blueprint was tested on three case study communities in Tasmania, Queensland, and Western Australia.

Using these case study findings, we developed a web-based blueprint for use by coastal communities to raise awareness of marine climate change and the potential flow on effects into regional coastal communities (coastalclimateblueprint.org.au). The general and locally specific information on marine climate adaptation as derived from the case studies is used for illustrative and guidance purposes. Using a Sustainable Livelihoods Analysis, an interactive assessment of community vulnerability to climate change allows community members or local governments to assess where their strengths and vulnerabilities may lie. For example, one community may have very high education levels and financial capital but be lacking in the necessary coastal infrastructure to allow the further development of commercial fisheries and aquaculture. This interactive web-based tool provides each community with a first-step indication of where specifically adaptation may be needed to ensure they remain sustainable into the future. The tool also provides a conduit for communities to undertake more detailed adaptation planning.

S12 Oral Presentations March 24
Linking climate change to marine management objectives

March 24, 11:20 (S12-10261), Invited

Fisheries management and climate change responses in Cambodia

Kao **Sochivi**

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Fisheries provide over 80% of the animal protein consumption, and is the mainstay in Cambodian diet. Additionally, in Cambodia, the fisheries sector contributes significantly to employment and livelihoods, to food security, to GDP and to foreign exchange balance. It provides full-time, part-time and seasonal employment for up to 6 million people and its value is estimated value about US$ 100 million per year. Climate change will have great impact on the fisheries sector; some species will likely benefit from changing conditions, possibly maintaining the overall fish productivity, while other species will be less adaptive and decline resulting an overall loss in biodiversity. The Cambodian fisheries sector is very vulnerability to climate change: a recent global study ranks Cambodia as 30th most vulnerable national economy to impact of climate change on fisheries. This talk will present Cambodian Fisheries Management and its responses to climate change in fisheries sector. An overview of (1) the current fisheries of Cambodia will be provided, along with (2) current Cambodian Fisheries Management and (3) planned responses to the climate change impacts with (4) conclusions and recommendations for the future.

March 24, 11:50 (S12-10256)

Managing in times of transition: How policy and management should react to climate change

Jake **Rice**

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Climate change is not a change in state from one set of quasi-equilibrium conditions to a different set. Climate change is a directional trend in a suite of environmental conditions. These variables may co-vary, but are not perfectly correlated. Even when the changes in ocean physics or chemistry are possible to linearize, at least over short time periods, biological responses to the changes may be non-linear, with different parts of a community having different triggers of their environmental "tipping points", with cascades possible. This means that if climate change considerations are going to part of policy and management, they must enter as policies and actions that are robust during periods of transition, not ones that will become effective someday, when either a new "equilibrium" of a changed ocean or some forecasting benchmark is reached (and soon passed).

Management during periods of environmental transition is particularly difficult, and some of the most spectacular failures in oceans management arose from maintaining "fixed regime" thinking when a population or community was in transition. Fortunately the Precautionary Approach gives direct guidance on how policy and management should operate during times of ecological transition; guidance that (unfortunately) is often overlooked, and often not implemented even when acknowledged as appropriate. This talk will illustrate the generalizations above with specific case histories and then present both a rationale for the correct application of the PA during climate change, ad some selling points to make the necessary actions more appealing to policy makers and managers.

March 24, 12:10 (S12-9546)

Governance challenges for marine climate hotspots

Marcus **Haward**

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Changes in climate are leading to warming in the ocean, with some regions warming much faster than others, with, *inter alia*, consequential impacts on and likely change to the distributions and abundance of key marine species. In addition these changes are likely to impact on regional food security, local economies, and social structures of the dependent human communities with concomitant and challenges to current governance arrangements. This paper focuses on marine climate 'hot spots', those areas warming faster than 90 per cent of the world's oceans and the governance challenges related to projected climate change impacts on marine resource utilization and management for both wild fisheries and marine based aquaculture.

March 24, 14:00 (S12-9863)

Institutional and organizational mapping – A powerful approach to identify opportunities and constraints for climate adaptation in fast warming regions

Leo X.C. **Dutra** and Marcus Haward

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Governance describes 'who' makes decisions, has powers and responsibilities, and 'how' they are exercised. It consists of two interacting components: a) institutions: the rules and protocols (*e.g.* laws, policies, customs) that shape human action, and b) organizations: the actors who define the rules for decisions. While institutions define how actors work, actors respond to institutions and may shape and modify them. Effective governance supports climate adaptation as it can help maintain or improve conditions of socio-ecological systems. The Belmont Forum supported GULLS project team includes partners from South Africa, Australia, India, Brazil, United Kingdom, United States, Madagascar, New Zealand, Canada, and Mozambique. It addresses broad issues that contribute to vulnerability in the marine and coastal environment. It connects leading researchers from regions around the world that are experiencing fast warming in the marine environment with potential for heightened social tensions as a result of the change. The governance arrangements across the GULLS partner countries are highly complex, dynamic and multi-level with numerous governmental, industry, community and non-governmental actors interacting within and across levels and authority domains. As a result we have developed a general framework for governance mapping that can be applied based on local needs. This paper outlines the framework; how it can be used; and discusses preliminary and lessons learnt by applying the framework in the SE fisheries in Australia.

March 24, 14:20 (S12-10069)

Effects of climate change on the world's oceans are not important in current marine management

Linus **Hammar**

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It is anticipated that carbon dioxide driven climate change and ocean acidification will result in unprecedented and possibly catastrophic ecosystem change. Any level of mitigation of such impact can be considered valuable from an ecological, social and economic, standpoint. One politically supported and important means of reducing carbon dioxide emissions is to increase the availability of renewable energy, including renewable energy from the oceans. In high latitude regions such as Scandinavia wind power is one of the renewable energy technologies with absolutely highest potential of growth and the greatest resources reside in offshore locations. However, the expansion of marine renewables is regulated through environmental legislation with great emphasis of local environmental impacts and little consideration of climate change and ocean acidification mitigation. In this Swedish case study it is argued that the widely applied precautionary principle collides with long term sustainability because of narrow systems boundaries in environmental legislation. Means of preventing climate change and ocean acidification are not explicit in either the Swedish Environmental Code or the important EU

Marine Strategy Framework Directive and are therefore rarely considered by marine management authorities. Instead, the precautionary principle has resulted in a disproportional high evidence burden on new technologies such as offshore wind power in comparison with established industries. In order to boost the expansion of new renewable energy technologies, and marine renewables in particular, there is a need of a wider systems thinking in marine management. The precautionary principle needs to be extended to effects of climate change.

March 24, 14:40 (S12-9998)

Uptake and pathways of coastal adaptation processes in Australia

Débora **De Freitas**[1,3], Laura Stocker[2] and Richard Kenchington[3]

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Coastal living countries such as Australia are the frontline of climate change impacts. With an extensive coastline of around 59,736 km including islands, Australia faces many coastal challenges. Complex interactions in biophysical systems, competing interests, multiagency management system, and fragmented governance framework present managers with a range of issues to consider. In Australia, as elsewhere, effective governance of coastal areas is challenged by: complexity of natural coastal systems; diverse uses of coastal areas; diverse jurisdictions and administrative bodies with coastal responsibilities (*e.g.* shipping/ports, planning, biodiversity management, fishing, recreation); diverse ways of understanding and appreciating coasts; and different perspectives on how it should be governed, managed, and used. It is now evident that climate science uptake requires both accessible knowledge systems and flexile structures and processes that facilitate policy actions in support of climate change adaptation. Researchers in a three-year (2010-2013) Australian social research programme, the CSIRO Flagship Coastal Collaboration Cluster, are seeking to understand how the dialogue between climate scientists and decision-makers can be enhanced in the complex and uncertain domain of coastal management and climate adaptation planning. In this talk, I will focus my discussion on the major outcomes of the coastal adaptation strategies. Major conclusions drawn reveal that current approaches to coastal adaptation planning are likely to be beset by: complex processes and uncertain understandings; diverse forms of legitimate knowledge; multiple sources of fragmented information; constrained and conflicting and planning horizons and timeframes; sensitivities regarding the release of information; and, the sense that coastal adaptation is political.

March 24, 15:00 (S12-10159)

Informing ecosystem-based management of the range extending long-spined sea urchin using a structured decision making process

Lucy M. Robinson[1,5], Martin P. Marzloff[1], Sarah Jennings[2], Stewart **Frusher**[1], Sam Nicol[3], Gretta Pecl[1], Ingrid van Putten[4], Alistair J. Hobday[4], Marcus Haward[1], Sean Tracey[1] and Klaas Hartmann[1]

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The poleward movement of species is one of the signatures of climate change and is resulting in changes in ecosystems that in turn are posing significant challenges for managers of marine resources and biodiversity. This is particularly the case where there are multiple stakeholders with different and often conflicting views on appropriate management action. A structured decision making process can assist managers in identifying some disparity between objective and subjective elements that may underpin stakeholder disagreement. In southeastern Australia the recent arrival and establishment of the barren's forming urchin (*Centrostephanus rodgersii* - which converts algae covered reef to barren reef) has resulted in impacts to valuable commercial and recreational reef fisheries and coastal reef biodiversity resulting in a range of ecological, social and economic consequences. We applied a Structured Decision Making process to assist managers and stakeholders with identifying cost-effective management interventions in barren and non-barren reef states that will best address the interests of the stakeholder groups. A workshop and two successive surveys were used to elicit information on stakeholder's objectives and preferences for management interventions. The consequences of alternative management scenarios

(in terms of potential benefits) were simulated for 10 years using a model that captures the dynamics of southeast Australian reef communities. Information on these benefits in combination with the estimated cost and feasibility of management interventions were then used to construct a cost-effectiveness ranking. The sensitivity of the management intervention ranking to the inclusion or exclusion of various components in the cost-effectiveness calculation was also explored.

March 24, 15:20 (S12-10040)

Climate change, science, and mariculture management in the United States and Brazil

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Climate change and shifts in ocean environmental conditions could have profound impacts on coupled human-marine systems. Nonetheless, how social forces shape the communication and application of scientific information related to changing ocean conditions to inform marine resource management is less understood. Marine aquaculture (mariculture) is emerging as one of the most important human uses of the ocean. Shellfish mariculture is especially vulnerable to climate change as warming ocean temperatures and acidification affect productivity, mortality, and shellfish safety. This paper combines insights from research conducted in two areas where mariculture is a key social and economic activity, New England, USA, and Santa Catarina, Brazil. Using data from phone surveys and in-depth interviews, we examined how social factors shape perceptions of different types of scientific information (*i.e.* regarding production technology, market economics, ocean acidification, and marine biotoxins) linked to mariculture management. Our study builds upon emerging findings within environmental social science that have identified distinct patterns in the way social forces shape perceptions of the validity and reliability of "production" versus "impact" science. Data from the U.S. and Brazil show that factors such as who funded the scientific research, whether the data highlight a problem that impacts shellfish productivity versus public health, and whether the data are used to inform regulatory decisions shape how both the general public and shellfish growers perceive scientific findings. These results illustrate a need for additional research on the social forces shaping perceptions of different types of climate-related marine environmental concerns.

March 24, 16:10 (S12-9893)

Mixed fisheries and ecosystem based management: Trade-offs and the importance of climate

Christopher **Lynam** and Steven Mackinson

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Fishing mortality targets for maximum sustainable yield, arising from single-species models for individual stocks, can not be achieved simultaneously through changes in fishing effort alone. We attempt to optimise potential changes in fishing effort for multiple fleets in order to meet current fisheries objectives and consider these in relation to the environmental goals set out by the European Marine strategy Framework Directive. We explore the effect of the proposed fishing strategy on the North Sea ecosystem by projecting forward an Ecopath with Ecosim model with and without climate forcing. In terms of biomass, many 'winners' arise through reduced fishing effort, including cod and sole, but other species such as megrim and whiting 'lose'. Such declines in biomass occur as a result of increasing predation from the growing stocks of predatory species, which include cod, saithe and seals. In general food web indicators alter slowly in response to changes in pressure and are also responsive to climate. Temperature effects have an explicitly modelled direct negative effect on cod that leads to decreases in biomass and catch as temperature increases. However, climate effects also perforate through the food web and can result in unintuitive results, *i.e.* haddock, a species that may benefit from explicit temperature rises, can support an elevated biomass of its predator, cod, despite unfavourable environmental conditions for cod. The trade-offs that arise from knock-on food-web effects of climate change are important to consider in long term management plans aiming to reconcile multiple objectives.

March 24, 16:30 (S12-9963)

Model-based integration of experimental results and human uses to identify management options for marine ecosystems under climate change

Stefan **Koenigstein** and Stefan Goessling-Reisemann

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Climate change is anticipated to cause increasing environmental stress to marine organisms, interacting with the pressure from human uses. We developed a system dynamics model with a regional focus on the Barents Sea, where considerable climate-related shifts in the marine ecosystems are already visible or expected in the near future. The model integrates population and community effects in the marine ecosystem and the impacts of human uses, building upon stakeholder participation to project changes in marine ecosystem services for the identification of management options.

We engaged stakeholders through personal interviews and a workshop, gathering knowledge and concerns about changes in marine food webs and identifying the most societally relevant ecosystem services in the region: fisheries, tourism and recreation, carbon uptake, and biodiversity. A social-ecological system model was developed to integrate ecosystem survey data and experimental results from laboratory (stress sensitivities and interactions between fish species) as well as mesocosm community experiments (shifts in primary production and lower trophic level dynamics) under future ocean warming and ocean acidification. Processes and mechanisms in the ecosystem and quantitative indicators for ecosystem services are integrated, to explore the consequences of changes in the marine food web for the provision of ecosystem services.

The model links climate change scenarios to the response of marine ecosystems and the impacts on human societies. It serves as a practical tool to engage stakeholders, discuss potential impacts and interactions of environmental and direct anthropogenic stressors and identify feasible adaptation strategies.

March 24, 16:50 (S12-9790)

Carbon capture and storage impacts on marine systems: Are local impacts good return for global mitigation?

Ana M. **Queirós** and Stephen Widdicombe

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The ocean is a sink for atmospheric CO_2. The long-term rise in ocean pCO_2 and reduction of pH associated with modern day energy consumption are already having significant ecological consequences for marine ecosystems. One of the available options to curb further increases in atmospheric CO_2 is the piping and injection of waste CO_2 gas from point-source producers into deep geological reservoirs, commonly termed as Carbon Capture and Storage (CCS). This technology has been tested and is ongoing, but the possibility of leakage is still a cause of great concern. In a recent mesocosm study, we found that CO_2 leakage from reservoirs can modify multi-functionality in local marine ecosystems. This effect was even greater at the injection phase, when CO_2 gas is pressurised into sub-seabed reservoirs, causing the release of toxic hypoxic and highly saline formation water previously trapped underground, onto the sediment surface. The effects of formation water onto sedimentary benthic communities and processes was striking , causing high rates of mortality and clear shifts in marine biogeochemistry locally. Given the present limited ability to project the macro-scale effects of leakages and until recently, the lack of understanding of the impacts caused by the release of formation waters, what direction should we take towards a holistic risk assessment of the CCS industry? We discuss how the cost-benefit analysis for local marine management can be done through a consideration of ecosystem services. This approach quantifies trade-offs between local impacts and global benefits via climate regulation.

March 24, 17:10 (S12-9965)

Impact of coral bleaching events and adaptive management of tourism in the Thai waters

Thamasak **Yeemin**, Watchara Samsuvan, Kanwara Sangmanee, Juthamart Putthayakool, Montaphat Thummasan, Mathinee Yucharoen and Makamas Sutthacheep

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The extensive coral bleaching events in the Gulf of Thailand and the Andaman Sea were recorded in the last two decades with clear spatial and temporal variations in the extent of coral bleaching and subsequent coral mortality. This study compared the impacts of the 2010 coral bleaching event on a coral community at Ko Yak, in the Eastern Gulf of Thailand and several reef sites of Mu Ko Surin, the Andaman Sea with implications for tourism management. Population densities of *Acropora* spp. and *Pocillopora damicornis* at Ko Yak decreased remarkably after the bleaching event. Low coral recruitment rates of *Fungia* spp. and *Porites* spp. were clearly observed. However, most tourists at Ko Yak preferred to enjoy some abundant reef fish, such as *Neopomacentrus anabatoides* and *Abudefduf sexfasciatus*. A proper measure is urgently needed to reduce the impacts from boat anchoring and waste water from tourist boats and to control tourist numbers at below carrying capacity of the diving site at Ko Yak. The 2010 coral bleaching event also resulted in obvious reduction of *Acropora* colonies at Mu Ko Surin however the coral recovery rates were relatively high. There are several reef sites at Mu Ko Surin which can be alternatively visited by tourists. A tourism management plan for Mu Ko Surin and other marine national parks in the Andaman Sea should be effectively implemented in consultation with the key stakeholders in order to mitigate any anthropogenic impacts on the coral reefs.

W1 Oral Presentations March 22
Addressing uncertainty in projecting climate change impacts in marine ecosystems

March 22, 09:00 (W1-10142), Invited

Projecting changes to living marine resources in an uncertain future

William W.L. **Cheung**[1], Rebecca G. Asch[2], Thomas Frölicher[3], Miranda C. Jones[1], Malin L. Pinsky[4], Keith Rodgers, Ryan R. Rykaczewski[5], Jorge L. Sarmiento[2], Charles A. Stock[6] and James R. Watson[7]

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Quantitative models of living marine resources (LMRs) assess the impacts of climate change and other human activities on marine ecosystems, and are used to evaluate the effectiveness of mitigation and adaptation measures. However, formal treatment of projection uncertainty in existing analyses and its implications for developing mitigation policies is uneven across studies and often lacking. In this paper, we draw from the experience of physical climate model inter-comparisons to outline a path for addressing this. Uncertainty in LMR projections arises from internal variability, model uncertainties, and future scenario uncertainties that cascade through physical and ecological sources creating a daunting uncertainty space. An "ensemble of opportunity" offers a starting point but (much like early climate model inter-comparisons) would markedly under-sample this uncertainty. Focused examination of under-sampled uncertainty dimensions is thus needed while noting that dominant sources of uncertainty vary by space and time-scale of interest. LMR observations summarized herein can provide constraints to refine uncertainty estimates and build confidence in projections. A strategy starting with first order consistency to mean metrics is suggested, with more refined comparisons following after explicit evaluation of relationships between retrospective and predictive skill. Many LMR observations suffer from potentially confounding effects of fishing and gear changes that can obscure climate signals. Improved accounting for these factors is essential for maximizing the data utility. The framework proposed herein could be applied to international initiatives such as the Fisheries Model Intercomparison Project (FISH-MIP).

March 22, 09:30 (W1-10265)

A statistical approach to model structural-uncertainty

Mark R. **Payne**

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A key aspect of any modelling endeavour is the choice of model structure: the way that the model maps the inputs to its outputs. However, in many branches of science, including marine science, the choice of model structure is not always obvious, and numerous alternative structures are equally feasible. Model structure therefore represents a key source of uncertainty in model development, and therefore in making projections, but can be particularly challenging to quantify. Fortunately, statisticians have developed techniques to evaluate and quantify this structural uncertainty using the so-called information-theoretic (IT) approach, although its use has not become widespread in marine science. In this paper I will illustrate how the IT approach can be used to address structural uncertainty in one of the most challenging problems in fisheries: the stock-recruitment relationship. I will first show how the approach quantifies the trade-off between predictive bias and variance. The use of the approach to identify the model structure with the most evidence supporting it will be demonstrated. Finally, the use of the approach to weight alternative model structures in a predictive context will be examined.

March 22, 09:50 (W1-10272)

A downscaling investigation of multi-model uncertainty of hindcasted and projected regional temperatures

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Different model parameterisations used for projecting future states of ecosystems and foodwebs can contribute uncertainty to projected outcomes. This uncertainty is particularly evident when multiple models are available for estimating the same response (*e.g.*, sea temperature, biomass of a fish population) in a given system. Here we evaluate the level of uncertainty in projections of an abiotic variable (sea temperature) as estimated by three different regional models of a large marine ecosystem (Baltic Sea), which are coupled via downscaling to a global model of climate-ocean dynamics. Using historical observations, we show that each model performs reasonably well, but has its own specific biases and uncertainties. Moreover, biases differ depending on season of the year, indicating that generalisations of uncertainty for a given season may not apply to other time seasons. All three models produce simulated temperatures whose variance underestimates that seen in nature. These analyses quantify some of the uncertainty that is present in model hind- and forecasts at a regional level. Potential solutions could include bias corrections and development of unweighted or weighted ensemble averages of hind- or forecasts, as well as continued development and implementation of process knowledge related to the phenomenon of interest.

March 22, 10:10 (W1-10062)

Uncertainties of model based assessment of climate change impact on marine ecosystems

Cosimo **Solidoro**, Giorgio Bolzon, Gianpiero Cossarini and Paolo Lazzari

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We implemented a global sensitivity analysis on a state-of-the-art 3D biogeochemical model of the Mediterranean Sea, currently applied in the framework of both climatological and operational oceanographic applications. The analysis required massive use high performance computational facilities (10000 1-year long simulations). We focused on the Mediterranean Sea because this basin is small in comparison to real ocean, so that computational burden is significantly reduced, but still large enough to be representative of the real ocean. In fact, the Mediterranean Sea exhibits large space and time variability in all biogeochemical parameters, presents all oceanographic processes, from large scale to sub mesoscale, and it is often considered to be a proxy for larger oceans.

Our results provide an estimate of the uncertainty induced on each model output assuming a 5% uncertainty in the value of each of the hundreds model parameters, together with an estimate of the cumulative effect of such uncertainty.

Results indicate that different model outputs are characterized by different degrees on uncertainty. Globally, the uncertainty is higher (up to 300%) in measures related to higher trophic level organisms, such as carnivorous mesozoopkanton, and lower for those related to planktonic primary producers, but for one specific group of plankton organism. Several outputs present pretty large uncertainty, but –globally— the cumulative effect of potential uncertainty in hundreds of model parameters add up to an error which is smaller than 25% for the majority of the parameters.

March 22, 11:00 (W1-10279)

Estimating variability and uncertainty in predatory relationships: A unified Bayesian framework for stable isotopes and fatty acid profiles

Philipp **Neubauer**[1] and Olaf P. Jensen[2]

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As a major structuring force in ecosystems, predation is a central component of many ecosystem models. However, quantifying the strength and variability of these relationships for entire communities remains a major difficulty. Stomach contents give valuable insights into predatory relationships of target species in high-value fisheries, but this approach is often impractical or not feasible at the community level. In such a setting, proxies of diet composition such as stable isotopes (SI) and, more recently, fatty acid (FA) profiles are useful and complementary tools for estimating predator prey relationships. Dietary FAs in particular have the potential to disentangle complex food webs owing to the large number of potential markers. However, sophisticated Bayesian methods and packages have only been developed to infer diets and trophic position from SI, and no comparable methods have been available for FA profiles. The combination of these two approaches has therefore been limited and qualitative. We propose a model-based framework for FA profiles that incorporates the Bayesian machinery employed in state-of-the-art mixing models for SI. Being model-based, the FA analysis can be explicitly integrated with analogous models for SI to increase resolution and clarify predator-prey relationships from trophic enrichment of SI. This unified framework provides both point estimates and probability distributions for individual and population level diet proportions. Applications to simulated and experimental data allow us to illustrate modeling strategies, demonstrate model performance and highlight the advantage of jointly using SI and FA to improve estimates of diet composition and variability. All methods and analyses are provided as an open source software package for the statistical computing environment R, and we anticipate further development to increase the applicability of our framework in complex food webs.

March 22, 11:20 (W1-9909)

Scaling up experimental climate change research: From individuals to the ecosystem

Ana M. **Queirós**[1], José A. Fernandes[1], William W.L. Cheung[2], Manuel Barange[1] and Stephen Widdicombe[1]

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Macro-scale models can be used to project the bulk properties of ecosystems, providing a holistic view of ecosystems where large scale research questions about global climate change can be addressed. The integration of detailed, species-level experimental information into such applications has been challenging because macro-scale models operate at much larger scales, typically including only generic descriptions of species. New generation models (like dynamic bioclimatic envelope models) now use large-scale environmental patterns projected by biogeochemical models, merging them with finer mechanistic descriptions of individual species responses to that environment. In a recent study, we used this approach to integrate, interpret, and use necessary, detailed, species-level experimental climate change in an ecosystem-level context. We found internal variability associated with multi-level responses of species to stressor combinations. This is a wider community gap particularly motivated by a lack of appropriate data for model development and parameterisation. Experimental research frequently focuses on short-term, individual-level impacts in isolation. However, ocean acidification and warming can impact distinct aspects of species ecology like metabolic rates and complex predator-prey interactions in different directions, challenging our ability to represent such responses in models and thus project how particular climate scenarios will drive species distributions in the long run. Such changes cannot be predicted by investigating individual level impacts in isolation, or by considering climate stressors separately. Reducing model internal variability to improve projections of species distributions will require greater focus of experimental ecologists to produce similar data on multi-scale responses to multiple stressors, in an ecosystem context.

March 22, 11:40 (W1-9921)

Ballast water management that adapts to climate changes and reduces harmful bio-invasions in marine eco-systems

Lauge B. **Rasmussen** and Mette S. Hansen

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The shipping ballast water is defined as water taken on board a ship to control trim, cargo, draught, stability and stress of the ship. Alien bio-organisms in ballast water have a range of ecological impacts, for instance reducing native bio-diversity, altering habitat and potentially the overall food-webs and eco-systems. Economic impacts include reductions in fisheries production and algae blooms harmful for fish farms, tourism and human health. Due to the rising temperatures of the Oceans, organisms that prefer a warm climate may take roots in marine ecosystems that were previously too cold for them. In addition, future changes of temperature, storm patterns and sea-currents may also change shipping routes and ballast water management practices. Based on methods like stock taking, trend tracking and scenario modeling the paper aims to evaluate possible ecological and economic impacts in marine ecosystem of changed factors in the shipping sector, for instance change of number, size, and design of vessels as well as treatment technologies of ballast water. New areas for shipping due to climate changes are also included. Our study would contribute to improve decision support tools, usable in shipping management and in development of international regulations for shipping with special focus on reducing the impacts in marine ecosystem. It can help to identify needs for change of regulations and shipping management procedures necessary to prevent even more harmful bio-invasions in the future.

March 22, 12:00 (W1-10271)

Dealing with uncertainty when developing socio-economic scenarios for North Atlantic fisheries futures

Manuel **Barange**[1], Christian Mullon[2] and José A. Fernandes[1]

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Scenarios are plausible representations of the future. When dealing with social and economic futures the development of scenarios provides a useful tool to deal with uncertainty. Rather than "predicting" or "projecting" the future, scenarios explore the consequences of given "futures", without associated probabilities. This approach also avoids normative dialogues by presenting every scenario without specific value loadings. Here we will present the results of work conducted under the EuroBASIN programme, linking the impacts of climate change on ecosystems and fish resources and those of economic globalisation and trade on the markets supported by fish trade (Mullon *et al*. 2014). The four scenarios considered (Baseline, Fortress, Global Commons, Free Trade) present contrasting views of the future of North Atlantic fisheries. The assumptions and limitations of this approach will be discussed in the context of the workshop objectives of dealing explicitly with projection uncertainties.

Mullon, C., G. Merino, J.A. Fernandes, W.W.L. Cheung, M. Barange 2014. A modeling framework for oceanic basins under double exposure. International Environmental Modelling and Software Society (iEMSs). 7th International Congress on Environmental Modelling and Software. San Diego, California, USA, Daniel P. Ames, Nigel W.T. Quinn, Andrea Rizzoli (Eds.). http://www.iemss.org/society/index.php/iemss-2014-proceedings (in press)

W2/W6 Oral Presentations March 21
Joint Brazilian Ocean Acidification Research and Surface Ocean-Lower Atmosphere Study (SOLAS) Workshop: Biogeochemical-physical interactions and feedbacks between the ocean and atmosphere

March 21, 09:00 (W2/W6-9897), Invited

Ocean acidification studies: The Brazilian contribution

Rosane Gonçalves **Ito**

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Studies on the oceanic carbonate chemistry have become of great interest to the international scientific community. Despite the high variability of oceanic CO_2 distribution, current studies indicate that anthropogenic carbon is present in various marine ecosystems, demanding more wide-ranging observational programs, focusing on the absorption of anthropogenic carbon and on the concomitant acidification caused by this absorption. The Brazilian Ocean Acidification Research Group (BrOA), formed by several national institutions, is conducting studies on ocean acidification in order to predict future impacts on foodweb dynamics and other ecosystem processes in the South Atlantic Ocean. The continuity of these studies is now imperative, through the identification of research priorities, as well as promoting closer national and international cooperation agreements.

March 21, 09:30 (W2/W6-10057), Invited

Toward the establishment of a Latin-American Ocean Acidification Network (LAOCA): The Chilean experience in OA research

Cristián **Vargas**[1,2,3], Marco Lardies[4,2], Bernardo Broitman[5,2], Cristian Duarte[6,2] and Nelson Lagos[7,2]

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5 Centro de Estudios Avanzados en Zonas Aridas (CEAZA), Coquimbo, Chile
6 Facultad de Ecología y Recursos Naturales, Universidad Andres Bello, Santiago, Chile
7 Centro de Investigación e Innovación para el Cambio Climático (CiiCC), Universidad Santo Tomas, Santiago, Chile

Ocean acidification (OA) it is a growing global problem that will intensify with continued CO_2 emissions, in consequence OA research is emerging as a critical field in marine science, and has the potential to change marine ecosystems and affect benefits to society. The major changes in ocean chemistry caused by increasing atmospheric CO_2 are well understood and can be precisely calculated; however, there are some uncertainty resulting from biological feedback processes, and the direct biological and biogeochemical effects of ocean acidification in marine ecosystems are less certain, especially for coastal ecosystems in Latin-American countries. Between 2009 – 2012 a formal Chilean Program in OA was established funded by the government (CONICYT), and now research on OA has growing as new programs in OA research has been established, mostly associated to multiple stressor effects in the coastal ocean affecting shellfish farming industry (MUSELS) and affecting the pelagic ecosystems in open ocean off Chilean waters (IMO). Here, we will present some examples of the Chilean experiences in OA research, focused both in carbonate system description and biological responses of marine organisms to OA research. Scarce studies have been published regarding to OA effects on local marine biota in Latin American countries. To fill these gaps in understanding of OA effects, a formal Latin American cooperation Program is needed. Here, we intend to promote the creation of *Latin American Ocean Acidification Network (LAOCA Network)*. LAOCA represents not only a way to spread knowledge on global climatic change among Latin-American scientists, but also a tool to provide a mechanism for educating scientists on best practices in chemical and biological techniques, which can improve the knowledge and skills for young researchers interested in this emerging research field.

March 21, 10:00 (W2/W6-10220), Invited

Understanding ocean acidification: What will be the consequences for commercial species?

Silvana **Birchenough**[1], John K. Pinnegar, Matthew B. Sanders[2] and Jeo Lee

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Evidence indicates that absorption of atmospheric carbon dioxide (CO_2) in the ocean has already decreased pH levels by 0.1 pH units since 1750, and CO_2 concentrations are projected to rise further by the end of the century as fossil fuel reserves continue to be exploited. To date, the majority of ocean acidification (OA) research undertaken has tended to concentrate on benthic or planktonic species which are of limited direct importance to fisheries and aquaculture. Furthermore, some of the available evidence is contradictory with some studies demonstrating that species are robust to lower pH whilst others show marked sensitivity. There is still much research needed to understand some of the observed organisms' responses to changes in pH under laboratory and under their natural environment. In the UK, fisheries generate more than £800 million of revenue per year and support 30,000 jobs. Aquaculture generates £350 million and supports a further 4,200 jobs. It is important to document the effects of ocean acidification on species of commercial importance. This presentation concentrates mainly on experimental work conducted on lobsters and scallops, providing further understanding on the effects of ocean acidification in connection to co-stressors, such as temperature and/or food availability. This work considers the main changes in the growth, development and shell composition of different species. The outcomes of this research are paramount to understand the future climate change scenarios, which could have important economic and environmental consequences in commercially important shellfish. This information is deemed important for policy makers, scientists and conservation colleagues working on ocean acidification research.

March 21, 11:00 (W2/W6-10187), Invited

Sensing marine carbon and oxygen dynamics with autonomous observation approaches

Arne **Körtzinger**

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Until today, undersampling in both space and time is a common trait in oceanographic research and still arguably poses the biggest obstacle to closer insight into and understanding of the dynamics and processes of the ocean. In the recent decade novel autonomous observational approaches such as voluntary observing ships, floats, gliders *etc*. have matured and are more and more adopted by the marine biogeochemical community. In my presentation I will provide new approaches and successful examples of carbon and oxygen measurements from such autonomous platforms to illustrate their potential for better sensing upper ocean dynamics of the marine carbon cycle.

March 21, 11:30 (W2/W6-10085)

Testing ocean biogeochemical models using combined measurements of atmospheric potential oxygen (APO) and Ar/N_2 ratio and oxygen/heat oceanic fluxes

Manfredi **Manizza**[1], Laure Resplandy[1], Sara Mikaloff-Fletcher[2], Cynthia D. Nevison[3] and Ralph F. Keeling[1]

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3 University of Colorado, Boulder, CO, USA

Ocean biogeochemical models embedded in the new generation of Earth System Models are the key tools used to predict the response of ocean biogeochemical cycles and marine ecosystems to future climate change. Their realism at capturing key features of ocean biogeochemical cycles in present climate conditions is the first requirement to be considered credible when projected into scenarios of future climate. Quantifying how well these models can reproduce the seasonal cycles of fluxes of heat and gases such as oxygen and argon is vital to assess their robustness. In order to evaluate models for this specific feature we propose to rely on the novel use of atmospheric observations of gases resolved at seasonal time scale and that are independent of terrestrial biosphere sources and sinks, allowing us to isolate ocean processes. Specifically, we will focus on the use of the ratio of seasonal amplitudes of atmospheric potential oxygen (APO) and Ar/N_2 that directly depend on the biogeochemical and physical ocean process, respectively. For this study, we analyze the results from a suite of state-of-the-art ocean biogeochemical models. Air-sea gas fluxes of these models are transported in the atmosphere by the same atmospheric model (TM3). We will then test the model results against both oceanic and atmospheric metrics and evaluate the models based on their performance. We will then discuss the potential and the limitation of these methods.

March 21, 11:50 (W2/W6-10169)

A snapshot of the marine CO_2-system in three coastal ecosystems in SE Brazil

Leticia C. **da Cunha**, Cíntia W. Coelho, Pedro W. Santos, Ricardo Keim, Helen Soares, Michelle P. Araújo, Cássia de O. Farias and Claudia Hamacher

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There is still much incertitude concerning the marine carbon cycle in coastal tropical/subtropical ecosystems, especially regarding their role as sinks or sources of CO_2 to the atmosphere. In addition to the paucity of data regarding sea-air CO_2 fluxes in coastal zones, very little is known about CO_2-chemistry in these areas. Over coastal ecosystems, including Brazil, these changes are less clear, due to a variety of reasons, among them i) the extreme ecosystem heterogeneity, ii) the fact that carbonate chemistry is strongly regulated by riverine and open ocean delivery of nutrients and biological processes in these areas, iii) natural variation of pH in these areas at daily and/or seasonal timescales, and iv) lack of observations and the inadequacy of global biogeochemistry models in resolving these areas.

Here we present a snapshot of the CO_2-system in three coastal ecosystems in SE Brazil: Barra Grande, a small, pristine, stratified estuary; Canal da Joatinga, an eutrophic channel connecting a coastal lagoons to the ocean; and Lagoa Rodrigo de Freitas, an eutrophic choked lagoon in Rio de Janeiro city.

Diurnal variability of biogeochemical parameters is extreme in the three ecosystems. Seasonal surveys have shown that physical forcing (tidal currents and winds) influence the system stratification, and therefore CO_2 saturation in its surface waters. Biological activity also largely influences the CO_2-system parameters, and it is commonly observed increasing dissolved CO_2 in bottom waters, for all three ecosystems, related to decreasing dissolved O_2 concentrations.

March 21, 12:10 (W2/W6-9818)

On the progress of the Brazilian Ocean Acidification Research Group: Two years of activities

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3 Universidade Federal da Bahia - UFBA, Salvador, BA, Brazil

The Brazilian Ocean Acidification Research Group (BrOA - www.broa.furg.br) has achieved its short-term goals (national network implementation, identification of the main Brazilian research groups studying ocean acidification (OA) in December 2013. The second report was released as a result of the III Brazilian Workshop on Climate Change and Costal Zones ('Florianópolis 2013') discussions, when the main points that will guide BrOA's future activities between 2014 and 2019 were identified, both individually and as group. To date, BrOA network is composed of 35 researchers from 9 Institutions, distributed into 16 associated laboratories in Brazil. During 2014, ongoing scientific projects on ocean acidification (OA) issues and related subjects were funded, and will begin their activities in different ecosystems along the Brazilian coast, and South Atlantic and Antarctic waters. The BrOA network leaders are now in close connection with decision-makers in Brazil to prepare a national inter-calibration exercise for OA-relevant seawater parameters. Internationally, BrOA is contributing to the GOA-ON measurement network, and now is strengthening contact with Latin America colleagues to start and support a regional OA network. Ocean acidification is still a very abstract concept in Brazil, thus needing more efforts of the academic community and stakeholders to reinforce the importance of OA investigation and comprehension for the whole world. Our first workshop will surely help to delineate the actions needed to better integrate BrOA group nationally, regionally and internationally.

March 21, 14:00 (W2/W6-9799)

Ocean acidification experiments on coccolithophores under controlled laboratory conditions

Marius N. **Müller**

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Marine calcifying phytoplankton (coccolithophores) is one of the most studied organisms in regard to ocean acidification. The past 15 years of ocean acidification experiments on coccolithophores have led to numerous published studies with partly contradicting results. Here, I will summarize my current understanding of coccolithophore physiology in regard to changing seawater carbonate chemistry and focus on the known underlying cellular mechanisms. Furthermore, I will give special attention to encountered pitfalls, advantages and disadvantages when conducting laboratory experiments with coccolithophores (*e.g.* batch, semi-continuos and chemostat cultures).

March 21, 14:20 (W2/W6-10233)

Ecophysiological responses of *Lithothamnion crispatum* and *Sonderophycus capensis* to alterations in temperature, pCO_2 and nutrients

Pamela Muñoz, Ellie Bergstrom, Cintia Martins, Eduardo Bastos, Alessandra Fonseca, José Bonomi, Leonardo Rorig and Paulo **Horta**

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Lithothamnion crispatum and *Sonderophycus capensis* are two cosmopolitan subtidal calcareous algae with different temperature affinities, calcification mechanisms and potentially threatened by global warming and ocean acidification. These species were exposed to conditions of elevated temperature, pCO_2 and nutrients, by means of an indoor microcosm, in order to evaluate the interaction among these factors and their effects on each species. The fluorescence analyses revealed that elevated temperature exerted a negative effect on the photosynthetic responses (ETR) in both species, decreasing the ETR by more than 70%. Likewise, the concentration of Chl-*a* decreased with elevated temperature for *L. crispatum*. However, the addition of CO_2/low pH without nutrient enrichment acted in an antagonistic manner with temperature, stimulating the maintenance of the ETR in short term. Calcification decreases were observed for both species mainly in conditions of elevated pCO_2. In conclusion, climate change scenarios interacting with local stressors as inorganic pollution, should impact these calcified organisms reducing general calcification independent of the mechanisms and their previous latitudinal distribution.

March 21, 14:40 (W2/W6-10180)

Seasonal and diel CO_2 fluxes variability at Rocas Atoll-RN

Barbara R. **Pinheiro**[1], Felipe L. Gaspar[1], Manuel J. Flores-Montes[1] and Nathalie Lefèvre[2]

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The Rocas Atoll was chosen for this study with the main goal of evaluates the role of a pristine reef ecosystem as a sink or source for the atmospheric CO_2. Discrete water samples were collected from surface of shallow tidal pools at the atoll ring, during the dry (October 2013 – February 2014) and wet (March – May 2014) seasons. It was measured the pH, temperature, conductivity, and total alkalinity (Rounds, 2012). Using the Excel macro CO2SYS with the carbonic acid dissociation constants of Mehrback *et al*. (1973) refitted by Dickson and Millero (1987) and the KSO_4 for the bisulfate ion from Dickson (1990) it was calculated the partial pressure of CO_2. It was employed the Sweeney *et al*., (2007) gas transfer velocity (K) and CO_2 flux was calculated as follow $F= K*K0*(pCO_{2sw} - pCO_{2\,atm})$, where k0 is the CO_2 solubility coefficient in sea water (Weiss, 1974). The meteorological data was obtained from Fernando de Noronha at National institute of space research, INPE. The results showed a predominance of pCO_2 sub saturation state inside the Atoll due to biological activity, ranging from the minimum 20µatm at 4pm (wet season) to 585 µatm at 5:30am (dry season). There was not observed seasonal variation on the pCO_2 values, but the CO_2 fluxes were more intense during the dry (-101±60.1 $mmolm^{-2}d^{-1}$, mean±sd) then in the wet season (-80 ±58.1 $mmolm^{-2}d^{-1}$) (Kruskal-Wallis, p= 0.044, α=0.05). The fluxes variability was influenced by the lower values of temperature and higher wind velocity at the dry season.

March 21, 15:00 (W2/W6-9888)

Evaluating qualitative dissolution indexes as proxies for ocean carbonate chemistry

Adriana R. **Perretti**[1], Cristiano M. Chiessi[1] and Ana Luiza S. Albuquerque[2]

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To understand modern and past changes in the marine carbonate system like ocean acidification (*e.g.* dissolution of $CaCO_3$) appropriate proxies are necessary. Methods known as carbonate dissolution indexes can indicate qualitative changes on the environmental properties as seawater carbonate chemistry. The preservation state of fossil planktonic foraminiferal tests found in the geologic record is a useful, accessible and simple dissolution index. Recently, the "*Globigerina bulloides* dissolution index" (BDX) was successfully applied as a proxy for dissolution and changes in deep water mass circulation. Nevertheless, the BDX was so far applied in a very limited number of down core studies. Here, we evaluate the performance of the BDX compared to two other non-destructive qualitative dissolution indexes (*i.e.* size normalized weight and area density analyses). These indexes were applied to a marine sediment core (*i.e.* GeoB6308, 39.30°S/53.97°W/3620m water depth) that recorded bottom water properties during the last 12 ka BP. We were able to determine how the dissolution indexes represent the changes between very corrosive waters occurring during the late glacial period, and less corrosive waters occurring during the Holocene. The results allow us to evaluate how sensitive these dissolution indexes are to changes on carbonate chemistry and if they can be helpful as a carbonate chemistry proxy for future acidification assessment projects.

March 21, 15:20 (W2/W6-10224)

The use of multiple lines of evidences to conduct risk assessment in sediments affected by CO_2 acidification

Manoela R. **de Orte**[1,2], T. Ángel DelValls[2], Augusto Cesar[1] and Inmaculada Riba[2]

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This study aimed to investigate the environmental impacts associated with the acidification of marine sediments subject to leakage of CO_2. A CO_2 bubbling system was designed in the laboratory for the conduction of a battery of tests and different "lines of evidence" (LOEs) were used to monitor the quality of sediments. Various pH treatments were applied in the experiments. The results reveled that mobilization of metals from contaminated sediments increased with acidification, while geochemical modeling suggested that pH decreases generally increased the concentration of their free forms. Organisms from different trophic levels were selected for experiments and lethal responses varied greatly between them. For fish larvae and clams 100% mortality was recorded at pH 6.0, while for amphipods this mortality rate was recorded at pH 6.5. Polychaetes were more resistant, since at pH 6.0 the survival rate was very high (~90%). Considering sublethal responses, 80% growth inhibition of microalgae was recorded at pH 6.0, while for sea-urchins, larval development was negatively affected in 50% of the population at pH 7.0. When organisms were exposed to metal contaminated sediments, toxic responses were observed at higher pH levels due to increased bioavailability of metals. Macrobenthic community structure is also affected by acidificaction. Besides, the bioaccumulation of some metals increase with pH decreases. The use of these multiples lines of evidence and the link of the results obtained under a weight-of-evidence approach will provide a strong tool to evaluate the risks related to Carbon Capture and Storage activities in the marine environment.

W3 Oral Presentations March 21
Effects of climate change on the biologically-driven ocean carbon pumps

March 21, 09:00 (W3-10004), Invited

Observational approaches to the biologically-driven ocean carbon pumps

Phoebe J. **Lam**

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The biologically-driven ocean carbon pumps are the soft tissue, the carbonate, and the microbial carbon pumps. In this talk, I will focus on observational methods for measuring the soft tissue and the carbonate pumps, and discuss their potential interactions with each other and their overall effect on atmospheric CO_2. Specifically, carbonate producers such as coccolithophores can affect the ability of the biological pump to draw down atmospheric CO_2 in two ways: (1) as part of the carbonate ($CaCO_3$) pump, lowering total alkalinity (TA) in the surface ocean during calcification, which would increase atmospheric CO_2; (2) through a ballasting effect that increases the magnitude and/or transfer efficiency of the soft tissue pump, which would decrease CO_2. While the effect of carbonate precipitation on alkalinity is well understood and can be modelled, the mechanism underlying the apparent carbonate ballasting effect is still debated. With ocean acidification anticipated to affect the calcification rates of carbonate producers, we need to understand whether the net effect on atmospheric CO_2 will be positive or negative. I will discuss some observational results behind this debate.

March 21, 14:15 (W3-9883), Invited

Current hypotheses explaining the long-term stability of marine dissolved organic matter

Thorsten **Dittmar**

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Marine dissolved organic matter (DOM) is an enigmatic pool of carbon. It originates largely from marine biota, but it contains more than a thousand times more carbon than all living organisms in the oceans combined. Accumulation occurs because a small fraction of fixed carbon resists microbial mineralization in the ocean for millennia. The reason behind the long-term stability of DOM remains unknown. It is also not known how the marine DOM pool will respond to ongoing global changes in seawater chemistry. In this talk I will discuss current hypotheses that have been put forward to explain the stability of DOM in the marine environment. Most likely interplay of different mechanisms causes some organic molecules to persist in the ocean for several thousand years. Shortage of essential nutrients, food web mechanisms, and gradients in microbial community structure may cause an accumulation of DOM over months to decades. During this intermediate accumulation, DOM can be subject to secondary, stabilizing abiotic modifications. An alternative idea proposes extreme substrate dilution as a stabilization mechanism, suggesting DOM stability may be independent of molecular structure.

March 22, 09:00 (W3-9940), Invited

The future of the ocean carbon pumps: A modeling perspective

Marion **Gehlen**

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Global climate change drives major changes in the world ocean. Modifications in ocean heat content, salinity, oxygen content and pH combine to alter the physical-chemical environment for marine life. Enhanced stratification and reduced nutrient supply to productive surface waters are expected to result in a decrease in global ocean net primary and export production. Earth system models project a ~ 9% decrease in global yearly NPP, respectively ~ 12% in export production by the end of the 21st century compared to the 1990ties in response to the IPCC high concentration pathway RCP8.5. Simulated changes in export production are remarkably consistent between models and the positive feedback to atmospheric CO_2 associated with decreasing export production is overall small. These results contrast with studies attributing a strong feedback potential to a changing biological pump (*e.g.* a ~ 225 ppm increase in atmospheric CO_2 for its complete shut-down) and prompt the question whether the fate of exported organic carbon is adequately represented in Earth system or large scale biogeochemical ocean general circulation models (BOGCMs). This lecture will introduce concepts underlying the representation of the biological carbon pumps in BOGCMS, their observational basis and evolution with time and increasing process understanding. It will cast model output in the light of constrains on modeled processes provided by data sets ranging from *in situ* to space-born observations. The complexity of model representations will be discussed with reference to the availability of data for independent model evaluation and suggestions for future priorities for model development and field observations, respectively experimental studies will be put forward.

W4 Oral Presentations March 21
Upwelling Systems Under Future Climate Change

March 21, 09:30 (W4-9970), Invited

Regional and global ramifications of eastern boundary upwelling

Enrique **Curchitser**[1], Justin Small[2], William Large[2], Kate Hedstrom[3] and Brian Kaufman[2]

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There is growing evidence that the large-scale climate affects the character of oceanic boundary currents and by extension their ecosystems. In this talk, we present results from a multi-scale climate model integration capable of regionally enhanced ocean resolution. The global model is the NCAR Community Earth System Model (CESM), in which the ocean component contains a high-resolution ROMS nest. We show results from implementations in both California Current System and the Benguela eastern boundary currents. The models have been integrated for over 100 years and we will show that the better representation of coastal currents has both regional and global ramifications to the climate system. Furthermore, we show that the character of the upwelling in each region is distinct leading to particular choices in the setup of the coupled model.

March 21, 10:00 (W4-10114)

Spatio-temporal structure of upwelling in an eddy resolving quasi-global GCM

Shoshiro **Minobe**

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Upwelling play important roles in marine ecosystem and biogeochemistry cycles, supplying nutrient and often carbon rich water to the euphotic, surface layer due to advection of upward velocities. Measurements of vertical velocities are practically impossible, and thus basic features of upwellings including their space and time distribution are not fully understood. In this paper, we analyze spatio-temporal structures of vertical velocities mainly at the basis of the surface layer (101 m) in an eddy resolving quasi-global GCM forced by high-resolution wind stresses derived from QuikSCAT satellite from 1999 to 2006. This QuikSCAT forced run started from the initial condition obtained from another run forced by low-resolution NCEP/NCAR. In order to avoid the influence of the artificial transition, the analysis period is set from 2001 to 2006.

Time-mean vertical velocities at 101 m indicate strong and broad upwelling in the central and eastern equatorial Pacific and in the equatorial western Atlantic. Coastal upwelling in the eastern boundary regions, on the other hand, exhibits much narrower structures near from the limited coast. Upwellings also distribute associated with the western boundary currents and their extensions. The steady meandering of the Kuroshio Extension and the Agulhas Return Current causes alternating upwelling/downwelling. Most of these features are also seen in the experiment forced by low-resolution NCEP/NCAR winds, but interesting differences occur for the eastern boundary upwellings. This indicates that for a correct upwelling simulation high-resolution winds are important even for high-resolution ocean model, suggesting inadequacy of the ocean-only downscaling forced by low-resolution climate model outputs.

March 21, 11:00 (W4-10154)

Simulating the variability of eastern boundary upwelling over the past millennium

Nele **Tim**, Eduardo Zorita and Birgit Hünicke

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The Eastern Boundary Upwelling Systems are highly productive areas in the world ocean. Nutrient rich, cold water is upwelled due to trade wind induced Ekman transport. Consequently, they are rich in pelagic fish biomass and important for coastal fisheries. Sediment cores and observations suggest climate forcing may influence the intensity of upwelling.

We investigate here the variability of upwelling in the major Eastern Boundary Upwelling Systems (Benguela, Morocco, California and Peru) as well as the upwelling in the Arabian Sea in long paleoclimate simulations over the past millennium.

The model data used for this analysis is the MPI-ESM-MR, the Earth System Model of the Max Planck Institute for Meteorology participating in the Climate Model Intercomparison Project (CMIP5). An ensemble of three simulations for the historical (1850 - 2005) and the past1000 (900 - 1850) are analysed. The vertical mass transport is used as upwelling index. The annual cycles of upwelling are realistically simulated. The internal forcing dominates the variabilities and trend of upwelling and its driving factors, like wind stress and sea level pressure.

Correlating the upwelling index of the realizations with each other, we find that most of the variability of upwelling up to centennial time scales does not show any imprint from external climate forcing. Only the Arabian Sea displays a possible long-term modulation by orbital forcing, which could be linked to the Monsoon intensity.

Our results indicate at these time scales a link between the upwelling indicators from sediment cores and external climate forcing is not warranted.

March 21, 11:20 (W4-10191)

Upwelling intensity, stratification, and nutrient supply trends in the California Current System

Michael G. **Jacox**[1,2], Steven J. Bograd[2] and Elliott L. Hazen[2]

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Bakun [1990] hypothesized increased upwelling in Eastern Boundary Currents under the influence of global warming, due to intensification of the land-sea pressure gradient. Though uncertainty remains, a number of studies support Bakun's hypothesis for the California Current System. At the same time, ocean surface warming is expected to increase stratification, inhibiting upwelling of deep water. Provided both of these trends exist, their influences on the upwelling of nutrients are in opposition; the dominant control and ultimate direction of nutrient supply trends are unknown. For the period 1980-2010, we examine upwelling intensity, background hydrography, and nitrate flux estimates from a regional circulation model combined with empirically derived nitrate models. Modeled upwelling intensity and stratification are compared to hypothesized trends, and their impacts on nitrate flux are reported. We also consider these results relative to the timescales of climate variability vs. long-term anthropogenic trends. Comparison of studies covering 1950-2000 and 1980-2010 indicates that even on 30-50 year timescales, variability may dominate. Over those two periods, the relationship between stratification and upwelling trends is reversed. From 1950 to 2000, increased upwelling was accompanied by surface warming (increased stratification) in the CCS, consistent with proposed long-term trends. However, from 1980 to 2010, upwelling intensity continued to increase while surface temperatures (and stratification) declined, both of which should theoretically increase nitrate flux.

March 21, 11:40 (W4-10205)

Climate change and coastal upwelling drivers

Marisol **García-Reyes**[1], William J. Sydeman[1], David S. Schoeman[2], Ryan R. Rykaczewski[3], Bryan A. Black[4], Sarah Ann Thompson[1], Arthur Miller[5], Andrew Bakun[6] and Steven J. Bograd[7]

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4 University of Texas, Marine Science Institute, Port Aransas, TX, USA
5 Scripps Institution of Oceanography, University of California, San Diego, La Jolla, CA, USA
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Given the importance of coastal upwelling to fisheries, coastal ecosystem services, and economic benefits to coastal communities, understanding and projecting the impacts of future climate change on upwelling areas is of significant interest. Coastal upwelling is driven by alongshore winds, which have been hypothesized to increase in eastern boundary upwelling systems (EBUS). However, upper ocean warming is also anticipated to enhance water column stratification, which could limit the efficacy (nutrient flux) of coastal upwelling. Although extensive work has been done on how winds and temperature are changing and projected to change, significant low-frequency climate variability and the poor representation of upwelling in earth system models has prevented a thorough assessment of climate change impacts on these systems.

To circumvent these issues, here we synthesize results from a combination of regional and global observations, reanalysis products, and model projections that investigate how the regional drivers of upwelling-favorable winds (land and ocean pressure systems) and stratification (ocean temperature), among other drivers of wind variability, have changed and how they are expected to change in the future. We discuss how these changes might impact the coastal upwelling process and ecosystems in each of the four main EBUS.

March 21, 12:00 (W4-10219)

Decadal variability of the Iberian Margin subsurface structure in response to global warming

Patrícia **Laginha Silva**[1], Paulo Relvas[1] and A. Miguel P. Santos[2]

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The strong dynamic link between the atmosphere and the ocean in upwelling regions makes them highly sensitive to global changes. This study describes the response, at decadal scales, of the subsurface structure of the ocean off Western Iberia to the observed global warming during the last 64 years (1950 to 2013). A particular attention is given to the long-term variability of the coastal upwelling that dominates the oceanography of the region during a large part of the year. We will investigate the long-term variability of the thermocline depth and the mixed layer depth, along with the temporal evolution of the stratification.

A generalized warming trend is observed in the subsurface coastal waters of the Western Iberia, more intense in the south. This warming is more intense in the upper layers above the thermocline with an intensification of the stratification. In the oceanic waters the warming is less intense in the upper layers with a diminishing of the stratification. About the thermocline characteristics is possible to observe that the upper and lower limits don't change much over the study time period. An evident consequence is the increasing of the thermocline gradient, not as result of its lower limit deepening or upper limit rising but due to the upper limit be much warmer through the years.

March 21, 14:00 (W4-10217)

Upwelling in the Arctic and Antarctic under climate change

Kenneth F. **Drinkwater**

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Although upwelling in the Polar Regions does not receive the attention that other upwelling regions do such as the Eastern and Western Boundary Current systems or the equatorial regions, it is important to recognize upwelling occurs in these areas with significant impacts. This is especially important since the Polar Regions are expected to undergo some of the largest changes under anthropogenic climate change. In the Arctic, sea ice has been declining rapidly. One consequence of this result is that the ice has been retreating away from many of the shelf regions. Once the ice extends seaward of the shelf break, wind-induced upwelling can occur. This in turn results in higher nutrients and increased primary production on the shelves and at the shelf break. Observations of recent upwelling onto the Arctic shelves will be presented along with possible longer term consequences. In the Antarctic, upwelling occurs around the continent associated with the Ekman response to the mean clockwise winds. The expected changes in these winds under climate change will be discussed as well as their implications on the climate, oceanography and biology of the region.

March 21, 14:20 (W4-10147), Invited

Of fish, seabirds, and trees: Present, past, and future of upwelling ecosystems

William J. **Sydeman** and the Past, Present and Future of Upwelling Team

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Upwelling ecosystems provide vital services to society yet are at risk due to ocean warming and potential changes in the timing and amplitude of winds and currents that drive vertical mixing and associated physical processes. I review unusual ecosystem variability and new investigations focused on the timing and intensity of upwelling off northern California. To date, key findings are as follows: (1) interannual variability in upwelling occurs in two orthogonal seasonal modes: a winter/early spring mode dominated by interannual variability and a summer mode dominated by long-term increasing trend; (2) the winter/spring upwelling mode is closely tied to the positioning and amplitude of the North Pacific High, and therefore to the large-scale climate variability;(3) there is substantial coherence in year-to-year variability between the winter/spring upwelling mode and upper trophic level demographic processes, including fish growth rates (rockfish and salmon) and seabird phenology, breeding success and survival; (4) the winter mode, which represents conditions prior to the peak of seasonal upwelling each year, is a better predictor of biological responses than the timing of the spring transition or the rate of upwelling during the peak of upwelling each year; (5) the wintertime NPH blocks onshore storm tracks and thereby influences local precipitation, hence tree growth in adjacent terrestrial ecosystems; as such, dendrochronological analyses indicate that winter upwelling variability has risen over the past 60 years, largely due to an unprecedented series of potent, downwelling-favorable climate anomalies; (6) the linear increases in summer upwelling are consistent with a mechanism proposed by Bakun (1990), but syntheses of global climate models indicate little support for this mechanism. Winds appear to be intensifying in other upwelling ecosystems as well, but the extent to which California results apply to other upwelling ecosystems is unknown.

W5 Oral Presentations March 21
Moving Towards Climate-Ready Fishery Systems: Regional comparisons of climate adaptation in marine fisheries

W5

March 21, 09:15 (W5-10091)

Cross-scale interactions in coupled social-ecological systems: An organizing framework for assessing climate impacts and adaptation in marine fisheries

Katherine E. **Mills** and Andrew J. Pershing

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Climate interactions with marine ecosystems and fisheries occur at a range of temporal, spatial, and social scales. Climate change typically implies change over a large area (*e.g.*, basin) and long timespans (*e.g.*, centuries). However, fish populations and fisheries are also affected by variability in the climate system at shorter time scales—from seasonal to decadal—and operational, investment, and management decisions must be made at these time scales. Fisheries also operate across multiple social scales; individuals, communities, corporations, and management institutions are affected by climate impacts that occur at different spatial and temporal scales, and their adaptation responses need to be appropriately aligned.

As tightly coupled social-ecological systems, marine fisheries must respond to climate impacts and adaptation constraints that occur within and across multiple scales. This presentation will propose a tripartite framework based on temporal, spatial, and social scales for organizing our current understanding of climate impacts and adaptation in marine fisheries. The conceptual basis of the framework will be developed, and examples of climate impacts on the marine ecosystem and consequent decisions faced within the fishery system will be discussed at multiple scales. A simplified version of this framework will be recommended as a basis for organizing and synthesizing contributions from subsequent presentations in this workshop.

March 21, 09:30 (W5-9983), Invited

Combining cause and effect: Impacts of climate change on global fisheries and consequences for the dependency of nations on fisheries

Manuel **Barange**, J. Scholtens, Edward H. Allison, Gorka Merino, Julia L. Blanchard, James Harle, J. Icarus Allen, Jason Holt and S. Jennings

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The objective of this workshop is to bring together scientists and practitioners from different regions of the world to document and compare how marine fisheries are responding to the impacts of climate change. In order to address this objective at the global scale practitioners need to respond to two questions:

a. What regional fisheries are more at risk
b. What aspects of the contribution from fisheries are more at risk

In this invited presentation we will attempt to provide a global picture of the differential impact that climate change is expected to bring to different regions (Cheung *et al*. 2012; Blanchard *et al*. 2013, Pecl *et al*. 2014), to start responding to the first question. We will then explore the contributions of fisheries (or dependency of fisheries) in terms of employment opportunities, food production and economic trade, to understand the differential levels of risk of climate change on the component of dependency (Barange *et al*. 2014). Combining "dependency" with projected climate change impacts provides a more complete picture of the consequences of climate change, and possibly an indication of the urgency nations will need when considering their adaptations to climate change in the fisheries sector.

If time allows, we will explore the above aspects in detail using Bangladesh as a particular case example.

March 21, 09:50 (W5-9835)

Governance and climate adaptation in marine fisheries: Social and institutional dimensions

Marcus **Haward**

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The UNDP has defined governance as "the system of values, policies and institutions by which a society manages its economic, political and social affairs through interactions within and among the state, civil society and the private sector" (UNDP 2007). In marine fisheries loss of economic benefit and social amenity can arise from governance failure, with impacts of over fishing, pollution, and poorly managed adaptation to environmental and climate change some examples. Social and institutional factors area key elements of effective governance. Viewing fisheries as social-ecological systems (SES) encourages inclusion of diverse components that are not usually considered together, ranging from understanding of ecologic and oceanographic characteristics through to consideration of social impacts and institutional arrangements. Drivers of adaptive capacity and resilience can be identified, prioritized and advanced. In practical terms, resilience and adaptive capacity are foundations for sustainability and link social and institutional factors to inform constructive dialogue about long-term planning and strategic decision-making underpinning appropriate governance of climate adaptation in marine fisheries.

March 21, 10:05 (W5-10104)

Developing adaptation pathways for climate-impacted and at risk fisheries in south-east Australia

Gretta **Pecl**[1], Stewart Frusher[1], Alistair J. Hobday[2], Sarah Jennings[3], Emily Ogier[1], Andrew Sullivan[4] and Tim Ward[5]

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Although changes in climate are already impacting marine ecosystems, the development of adaptation options has lagged considerably behind that of terrestrial systems. Regions experiencing high exposure to key climate drivers, like south-east Australia, represent prime locations for assessing impacts and developing, evaluating and implementing adaptation options to cope with a changing future. Institutes within the five jurisdictions of the south-east have been proactive in establishing a formal collaborative structure (the South East Australia Program) to facilitate linkages between biophysical, socio-economic and governance domains, providing solid foundations to develop and implement adaptation options. Using rock lobster, abalone, snapper and blue grenadier fisheries as case studies, we detail how climate change may intersect with the specific management tools and structures for each fishery and use a combination of stock projections, scenario development and identification of critical thresholds to generate likely future scenarios. Development of adaptation pathways, in close consultation with industry and resource managers, will allow a balanced combination of management responses that can be introduced now, through to medium and longer-term responses. Central to our approach is the development of a clear understanding of what values the fisheries are being managed for by identifying objectives of management and understanding how different groups of stakeholders weight these. This will allow adaptation options to be ranked, highlight where stakeholder conflict may arise, and enable relevant performance indicators and metrics to be identified, in a transparent and contextually relevant framework.

March 21, 10:20 (W5-10080)

Managing United States fisheries in a changing climate

Wendy **Morrison**[1], Roger Griffis[1], Jon Hare[2], Valerie Termini[1] and Mark Nelson[1]

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This talk will discuss fisheries management in the United States. One of the first steps in understanding potential impacts of climate change is determining the vulnerabilities of the managed species. We have developed a methodology for estimating the relative vulnerability of species to climate change. The methodology uses expert opinion to rank species according to their exposure to and sensitivity (life history attributes that allow resistance, resilience and adaptability) to environmental change. Understanding potential vulnerabilities will allow management to consider management approaches that either reduce stock vulnerabilities or have the flexibility needed to adjust as changes occur.

The ability of fisheries managers to respond to climate change can be affected by both the overall governance structure of the management system as well as the specific management approach implemented. In the United States, most regulations are developed via one of eight regional fishery management councils. The governance of each Council is established by law, limiting the flexibility of the system to respond as stocks shift their distribution into the jurisdiction of a neighboring Council. Approximately 33% of U.S. federally managed stocks are managed under catch shares (rights-based management), which can both help and hinder management flexibility. Catch share management can improve a fisherman's ability to adjust to changes in catch composition by allowing him the freedom to decide when and how to fish. However, expensive permits and limited availability of quota can limit his ability move into and out of fisheries as species respond positively or negatively to climate change.

March 21, 11:00 (W5-9899), Invited

A quantitative metric to identify critical elements within seafood supply networks under a changing climate

Éva E. **Plagányi**[1], Ingrid van Putten[1], Alistair J. Hobday[1], Olivier Thébaud[1], James Innes[1], Lilly Lim-Camacho[1], Ana Norman-López[1], Rodrigo H. Bustamante[1], Anna Farmery[2], Aysha Fleming[1], Stewart Frusher[2], Bridget Green[2], Eriko Hoshino[2], Sarah Jennings[2], Gretta Pecl[2], Sean Pascoe[1], Peggy Schrobback[3] and Linda Thomas[1]

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A theoretical basis is required for comparing key features and critical elements in wild fisheries and aquaculture supply chains under a changing climate. Here we develop a new quantitative metric that is analogous to indices used to analyze food-webs and identify key species. The Supply Chain Index (SCI) identifies critical elements as those elements with large throughput rates, as well as greater connectivity. The sum of the scores for a supply chain provides a single metric that roughly captures both the resilience and connectedness of a supply chain. Standardized scores can facilitate cross-comparisons both under current conditions as well as under a changing climate. Identification of key elements along the supply chain may assist in informing adaptation strategies to reduce anticipated future risks posed by climate change. The SCI also provides information on the relative stability of different supply chains based on whether there is a fairly even spread in the individual scores of the top few key elements, compared with a more critical dependence on a few key individual supply chain elements. We use as a case study the Australian southern rock lobster *Jasus edwardsii* fishery, and also apply the index to an additional four real-world Australian commercial fishery and two aquaculture industry supply chains to highlight the utility of a systematic method for describing supply chains. Overall, our simple methodological approach to empirically-based supply chain research provides an objective method for comparing the resilience of supply chains and highlighting components that may be critical.

March 21, 11:20 (W5-9961), Invited

Some solutions for marine Ecosystem-based Fisheries Management in a changing climate

Jason S. **Link**, Roger Griffis and D. Shallin Busch

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Climate change is occurring, with several impacts to marine ecosystems and the fisheries that depend on them. The impacts are increasingly well known across a wide range of species and ecosystems. The challenge is how to account for these impacts as we manage living marine resources. If one examines a generalized marine resource management context, there are several entry points at which climate impacts could be considered. Examples from fisheries, conservation (*i.e.* Protected/Endangered/ Threatened) species, habitat, aquaculture, and integrated ecosystem assessments demonstrate where in the scientific and assessment process climate can be accounted for to provide modified, climate-savvy advice. We provide examples from a wide range of these applications. Certainly there is much room to advance the science, particularly exploring a full suite of adaptation strategy scenarios. To that end, we describe an information pyramid to ultimately produce and deliver such climate savvy science, especially identifying common needs and solutions. Furthermore, despite widespread perceptions, we assert that we do know enough to provide climate-savvy advice now, and certainly we do not have the luxury of waiting address these climate impacts as we manage marine ecosystems and their component fisheries. Identifying general principles, best practices, and useful tools remains a valuable outcome for the discipline to explore.

March 21, 11:40 (W5-10090)

Can we give good stock assessment advice in a changing climate?

Jacquelynne R. **King**, R. Ian Perry, Jean-Baptiste Lecomte and Andrew Edwards

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It is important to recognize that agency resources are a limiting factor in adapting fishery processes, such as the provision of scientific advice and management decision-making, to climate change. To date, the success of incorporating climate forcing or even environmental forcing, into operationalized stock assessment advice has been limited. That is not to say that the scientific literature has not provided many examples of stock assessment models that include environmental variables or indicator-based ecosystem assessments. The few operationalized successes appear to be in regions where a scientific champion has authority to develop and implement a revised stock assessment process and also has the resources to hire a scientific team with the expertise to deliver ecosystem-based management. Some of the scientific challenges have been: (i) lack of long-term monitoring programs for fundamental environmental indices and the subsequent reliance on proxy variables; (ii) lack of understanding the underlying mechanisms relating climate forcing to population dynamics or a change in the nature of the mechanisms; and (iii) how to include uncertainty and risk analyses in the provision of stock assessment advice. Management strategy evaluation is a fundamental requirement to move the stock assessment process into the delivery of scientific advice given climate change. This tool could be coupled with an evolutionary (not revolutionary) move to an ecosystem approach to fisheries management in order to provide stock assessment advice in a changing climate. In this presentation, we discuss these concepts and suggest alternative approaches to incorporating such information when the necessary agency resources may not be available.

March 21, 11:55 (W5-10253)

Setting biological reference points under a changing climate

Anne B. Hollowed[1] and Cody **Szuwalski**[2]

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Climate change is expected to impact the distribution, phrenology and abundance of commercial fish and shellfish through direct and indirect pathways. The temporal signature of these projected changes will differ from interannual, decadal, and multi-decadal variability and thus may necessitate new approaches to setting biological reference points for management. This issue presents a dilemma because stock projection models must carry forward reasonable harvest control rules that simulate fishers and managers responses to the changing availability and catchability of target species as well as fish responses to changing ocean conditions. To project theses forward, social and natural scientists must work together to identify: (a) the likely policy frameworks that will govern fisheries in the future, and (b) the tactical and strategic measures needed to implement these policies. In this paper we explore the potential impacts of climate change and harvest strategies on key fish and shellfish populations and we introduce a framework for projecting future responses of fish and fisheries.

March 21, 16:25 (W5-9884), Invited

Increased abundance and spatial expansion of Northeast Atlantic mackerel (*Scomber scombrus*) according to swept-area trawl surveys in the Northeast Atlantic 2007 to 2014

Leif **Nøttestad**[1], Kjell R. Utne[1], Gudmundur J. Óskarsson[2], Sigurður Þ. Jónsson[2], Jan Arge Jacobsen[3], Øyvind Tangen[1], Valantine Anthonypillai[1], Jens Christian Holst[4], Teunis Jansen[5] and Aril Slotte[1]

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The Northeast Atlantic (NEA) mackerel (*Scomber scombrus*) is a highly migratory, dynamic and widely distributed pelagic fish species. Mackerel play a key ecological role in coastal and oceanic ecosystems and are one of the most valuable fish stock in the North Atlantic. They are effective schooling predators on zooplankton and smaller fish, feeding competitors for other pelagic fish and prey species for larger fish, seabirds and marine mammals. The estimated abundance from standardized trawl surveys increased from 1.7 million tonnes in July-August 2007 to 9.0 million tonnes in July-August 2014. The mackerel stock has also expanded their feeding areas significantly from 1.0 mill. km^2 in 2007 to 2.5 mill. km^2 in 2014 mainly towards northern and western regions of the Nordic Seas. The mean density has also increased from 1.61 tonnes*km^{-2} in 2007 to 3.67 tonnes*km^{-2} in 2014. The temperature conditions in the upper water masses set an outer boundary for mackerel. The available habitat with acceptable temperatures (> 6-7°C) for mackerel has also increased in the Northeast Atlantic during the last 10-15 years, providing mackerel with larger and larger feeding areas. The main reason for the greatly expanded feeding area for mackerel is due to a record high stock size, combined with available food. A large stock need much space. Five of the strongest year classes throughout the entire time series, has come after year 2000. The mackerel is spawning from January to July over an enormous area, which result in a high probability for successful annual spawning.

March 21, 16:45 (W5-10170)

Slow management during rapid ecosystem change: How rapid warming drove the collapse of Gulf of Maine cod

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Conditions in the ocean and the atmosphere vary across a range of time-scales. Biological processes within an ecosystem integrate these scales and determine the rate and magnitude of variability in the ecosystem. Fisheries management also has time scales associated with the cycle of assessment and quota setting that typically range from annual-to-multiannual. Assuming assessments are accurate, the management time scale should be able to detect and correct for slow changes in the ecosystem. However, if conditions change rapidly, the management cycle can struggle to keep pace. From 2004 through 2013, the Gulf of Maine warmed at a rate of 0.23° yr^{-1}, one of the strongest decadal trends any marine ecosystem has ever experienced. This trend led to widespread changes in the ecosystem and coincided with the collapse of the fishery for Gulf of Maine cod. Error in projections from the Gulf of Maine cod stock assessment are strongly correlated with temperature. This error appears as elevated mortality, especially on young fish. Not accounting for this extra mortality led to optimistic projections and thus to fishing mortality rates that were consistently above targets. Directly incorporating temperature into the projections would have led to improved abundance estimates and may have avoided the collapse that is currently underway. Fisheries management has traditionally relied on historical patterns and used past performance of a stock as a basis for projections. As we encounter conditions with no analogue in our recent history, failures in our backwards-looking process will become more common.

March 21, 17:00 (W5-9992)

Observed impacts and adaptation strategies for coastal fisheries in south-east Australia

Stewart **Frusher**[1], Gretta Pecl[1], Alistair J. Hobday[2] and Gustaaf M. Hallegraeff[1]

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Empirical data from the southeast region of Australia demonstrates that rapid warming of this "hotspot" has been occurring since records began in the 1940s. Prior to the 1990s, when clearer evidence of rapid climate warming became more apparent, changes in the abundance of key fished species was mostly linked to fishing activity. Since the 1990's, closer scrutiny of relationships between physical factors such as water temperature and fish distributions, including poleward range extensions, have shown changes in coastal distribution and abundance in all tropic levels. However, while many changes in the productivity of coastal species have been difficult to correlate with specific physical exposure variables, there has been a range of observed changes from changing abundances of commercial, recreational and "pest" species to changes in species composition and spread of harmful algal bloom species impacting aquaculture and fisheries. These have all resulted in either autonomous or planned adaptation by industry or Government. This presentation will outline both the impacts and the subsequent adaptations to-date.

March 22

W5

March 22, 09:00 (W5-9954), Invited

Climate change and UK fisheries – Exploring adaptation actions, perceptions within the industry and the challenge presented by fish stocks that move across international boundaries

John K. **Pinnegar**, Miranda C. Jones and Paul Buckley

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In the United Kingdom, a Climate Change Act (law) was introduced in 2008 requiring that a risk assessment is carried out every 5 years to determine how industries might be impacted by climate change. The government can require sectors to put in place measures so that they remain robust to emerging threats or are able to capitalise on future opportunities. Climate change is having a profound impact on UK fish populations with 70% of species having responded to warming by changing distribution and/or abundance. Fish distributions have shifted northwards by distances ranging from 48 to 403 km since the 1980s.

The UK fishing industry includes operators of varying adaptive capacity. The ability of some segments to adapt is more constrained than others, notably small vessel operators may be particularly vulnerable. Operators face constraints on their ability to travel distances to reach their favored fish stock, the time they are able spend sea and their access rights to catch particular species (quotas). The key adaptation actions explored here include:

1. Travelling further to fish for current species, if stocks move away from UK ports.
2. Changing gear to fish for different species, if new or more profitable opportunities become available.
3. Developing routes to export markets to match changes in catch supplied.
4. Stimulating domestic demand for a broader range of species.

The perceptions and priorities of stakeholders in the UK fishing sector have been explored in a series of recent studies, as well as potential barriers to successful adaptation.

March 22, 09:20 (W5-9904)

Observed and predicted impacts and adaptation strategies for pelagic fisheries in south-east Australia

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Pelagic fisheries in Australia target a wide range of species, some of which modeling and observations suggest face challenges due to regional climate change. In this presentation, we describe the evidence for recent climate-related impacts on the distribution of a range of pelagic species, and the impact for dependent fisheries. These changes are particularly notable in south-east Australia—a marine warming hotspot. To prioritize adaptation action for these species we describe a risk-based approach developed in partnership with managers from across the region. The potential adaptation strategies occur at a range of time scales, and the first steps down these adaptation pathways is just beginning. For example, seasonal forecasting is used in several fisheries as a risk-based approach to better respond to changes in regional oceanography that impact production and management decisions. We also describe the range of long-term strategies being discussed amongst managers and policy makers in this region.

March 22, 09:35 (W5-10018)

Managing Pacific tuna stocks under strong fishing pressure and climate change impact

Patrick **Lehodey**[1], Inna Senina[1], Simon Nicol[2], John Hampton[2] and John Sibert[3]

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The four main tuna species that underpin Pacific Ocean fisheries, skipjack tuna *Katsuwonus pelamis*, yellowfin tuna *Thunnus albacares*, bigeye tuna *T. obesus* and South Pacific albacore tuna *T. alalunga*, yield combined harvests well in excess of 4 million tonnes each year, and support fishing operations ranging from industrial fleets to subsistence catches. Part of this catch and activity contributes to high government revenue of Pacific Island countries and territories (PICTs). Because tuna are highly migratory, management of their fisheries involves the cooperation of all countries within the distribution zones of the main species, and the distant water fishing nations from outside this region that also harvest these fish. While the impact of natural climate variability, *e.g.* the El Niño Southern Oscillation, has been shown of influence on the distribution, abundance and catchability of tunas, results of simulations using IPCC scenarios for the 21th century suggest potential strong effects on distribution and abundances. Based on these results, the challenges of future management of tuna stocks will be discussed.

March 22, 09:50 (W5-10196)

What are the key challenges to climate change adaptation in Bering Sea and Aleutian Islands groundfish fisheries?

Alan **Haynie**

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Approximately 2 million tons of groundfish are caught annually off the coast of Alaska in the Bering Sea and Aleutian Islands (BSAI). Ecological research has indicated that the spatial distributions of some fish populations are shifting slowly northward, but research on fleet behavior indicates that the largest fisheries are not currently shifting in the same manner for various economic reasons. While fisheries can adapt to a changing environment, they are constrained both by management institutions and by our understanding of how the institutions impact fishers. This talk addresses several key challenges to adaptation that confront fisheries. First, catch share programs allow vessels to adapt the timing and focus of their fishing and production, but have assigned fishing rights to different species in a manner makes some fisheries highly specialized. Second, marine mammal protective measures are linked to definitions of unfished biomass that may close fisheries some years in a changing environment. Third, the 2 million ton BSAI "ecosystem cap" leads to a large additional buffer between actual catch and the species-specific allowable biological catch (ABC) for some species but not others. Finally, effort and cost data allow us to consider the economic impacts from different management paradigms (*e.g.*, maximum economic yield) that may provide different long-term prescriptions for fishing effort and harvest in light of uncertainty about future recruitment to different fisheries. Here we discuss research that is necessary to better understand how these challenges are interrelated and how management can improve welfare in face of these challenges.

March 22, 10:05 (W5-10081)

The role of institutional complexity, historical allocations, and changing demographics in management performance for a climate-changed ecosystem: Lessons from the US mid-Atlantic summer flounder fishery

Chris **Kennedy**

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Climate change is predicted to result in significant and complex changes to marine ecosystems and the fisheries they support, with the potential for large-scale and persistent redistribution of catch potential throughout the world. The Mid-Atlantic Bight (MAB) – located off the coast of the mid-Atlantic coast of the United States – is an excellent case study for understanding how climate change may impact fisheries: isotherms in the MAB have been shifting northward at 20-100 km per decade, temperatures have been warming at nearly twice the global rate, and many fish species in the region appear to be shifting northward. Further, there are numerous jurisdictions managing recreational and commercial fleets that prosecute dozens of species. One of these species–summer flounder (fluke)–has exhibited a notable northward movement over the last 40 years, with the last 15 years characterized by dramatic swings in recreational harvests and significant overages by northern jurisdictions, in part due to state-level allocations that no longer reflect the availability of fish to anglers. This research presents insights from the summer flounder fishery that are generalizable to other fisheries, with a particular focus on the role of allocation flexibility and management decentralization, and the importance of responsive recreational catch monitoring for a multi-species fishery where different taxa exhibit non-uniform biological and behavioral responses to temperature change.

March 22, 10:20 (W5-10094)

Adaptation to climate variation in a multispecies fishery: The West Coast groundfish trawl fishery

Lisa **Pfeiffer**

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The West Coast groundfish trawl fishery lands 26 percent of all fish, including shellfish, landed on the West Coast of the United States. However, the average West Coast groundfish trawl fishery participant receives only about 40 percent of their annual revenue from groundfish. The other three fisheries that make of the majority of extra revenue are the Dungeness crab, pink shrimp, and Alaska pollock fisheries. The abundance and timing of maturity of these target species are each highly driven by climatic cycles. In this paper we explore the drivers of participation in and allocation of time between fisheries when harvesters participate in multiple fisheries. Prior to the transition to a catch share management system in 2011, the groundfish fishery was primarily driven by management. Season openings and trip limits restricted landings, and participation in other fisheries potentially involved a trade-off of lost groundfish landings. After the transition to catch shares, we observe shifts in timing and participation more closely related to the climate-driven biological cycles of crab, shrimp, and pollock. Going forward, we expect fishermen allocate time between fisheries by maximizing net revenue from participation in the entire portfolio of fisheries available to them. The expected revenue and costs of each will at least partially depend on climate factors. Climate projection models can be used to predict how the patterns of participation and revenue will change in the future.

March 22, 11:00 (W5-10176)

Adaptations of fish and fishing communities to rapid climate velocities

Malin L. **Pinsky**[1], Kevin St. Martin[1], Eli Fenichel[2], Bonnie McCay[1] and Simon Levin[3]

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Changing climates have and will continue to drive widespread shifts in species distributions and abundances. In turn, spatial shifts present a unique set of challenges and opportunities to fishers that affect where, when, how hard, and for which species they can fish. Here, we examine two case studies from the northwest Atlantic. As temperatures in the region have warmed rapidly, summer flounder (*Paralichthys dentatus*) and red hake (*Urophycis chuss*) populations have shifted north rapidly. Fisheries landings have also moved north, but at substantially slower rates. Evidence from logbook data reveals complex patterns of adaptation modified by social, economic, and regulatory factors, including longer travel times for low latitude fishers. In both cases, species' responses lead them to cross management boundaries, violating the "clear boundaries" principle for sustainable management of the commons. Simulation models also reveal how the ability of fish populations to survive the cumulative impacts of climate and fishing depends on the adaptation behavior of fishers. More broadly, our central premise is that the feedbacks between ecological and human communities cannot be studied in isolation; nor can they be understood outside the social, economic, and institutional context of fishers' decision-making.

March 22, 11:15 (W5-9994)

Reel change comes at a price: The future of Bering Sea (AK) fisheries under climate change

Kirstin K. **Holsman**[1], Kerim Aydin[2], Jim Ianelli[2], Anne B. Hollowed[2], Alan Haynie[2], André E. Punt[3], Al Hermann[1], Nicholas A. Bond[1] and Georgina Gibbson[4]

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Climate change is expected to impact marine ecosystems globally, with largest changes anticipated for arctic and sub-arctic ecosystems. The 2-4^{o}C projected increase in sea-surface temperature for Alaskan (USA) marine systems may alter trophic interactions, ecosystem productivity and regional fisheries. Yet projected changes to fish and fisheries can vary considerably between models, adding uncertainty and complexity to management strategies. Here we discuss results of a sensitivity analysis of projections to model assumptions and formulations. Specifically, we used time-series extracted from hindcast (1979-2012) and IPCC scenario-driven ROMS-NPZ models to fit and project a climate-specific multi-species stock assessment model (MSMt) forward to 2040. When we compared model projections under climate change to scenarios based on constant future conditions set at mean historical values, we found declines in estimated acceptable biological catch (ABC) for pollock and declines in recruitment for both pollock and Pacific cod. Scenarios with predation had the largest projected declines in ABC, whereas projections without predation or bottom-up controls on recruitment had the lowest projected changes in ABC. When fishery value was additionally considered, the economic implications of the projections were even more disparate. This work emphasizes the need to evaluate multiple future scenarios and model structures when projecting climate effects on fisheries.

Abstracts
Poster Presentations

S1 Posters
Role of advection and mixing in ocean biogeochemistry and marine ecosystems

S1-P1

Microbial biogeochemistry in the Southern European Seas: The multidisciplinary ADREX survey

Rosabruna **La Ferla**[1], Maurizio Azzaro[1], Gabriella Caruso[1], Renata Zaccone[1], Giovanna Maimone[1], Franco Decembrini[1], Rodolfo Paranhos[2], Anderson S. Cabral[2], Marco Pansera[3] and Giuseppe Civitarese[4]

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In the frame of PERSEUS EU Fp7 project, part of the multidisciplinary oceanographic campaign ADREX was dedicated to microbial biogeochemistry and its possible connection with climate change in Southern European Seas, according to the European MSFD. Within the Mediterranean, the main physical pressures in the Adriatic-Ionian system are: the dense water formation by both shelf processes in the northern Adriatic and open-ocean convection in the southern basin; the Bimodal Oscillating System mechanism that reverses the Northern Ionian Gyre circulation on decadal scale. In this context, selected stations were investigated in the Ionian and Adriatic Seas (February 2014) by means of seawater samples collection from the surface to a maximum depth of 3698m. Microbial biogeochemistry was studied by assaying: prokaryotic abundance and biomass (image analysis and flow cytometry), microbial enzymatic activities, respiration, chlorophyll *a* and phaeopigments concentration, viral abundance. The hydrological properties were also monitored.

The effect of dense shelf water cascading event on microbes was revealed by the different distribution of biomass and activities in the studied areas. In the Ionian Sea, below the photic layer, phototrophic cells belonging to *Prochlorococcus* and *Synechococcus* spp. were often detected by both cytometric and microscopic analyses. Furthermore, differences in the enzymatic activities were found between western and eastern sides, as well as between photic and aphotic layers of Adriatic and Ionian basins, in relation with anthropogenic and/or natural impacts. Since the microbial community rapidly responds to environmental changes, the microbial approach appears to be useful to follow the evolution of the Mediterranean.

S1-P2

The use of physical decomposition to analyze interannual climate variability in the southern Indian Ocean

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This study physically decomposes SODA (Simple Ocean Data Assimilation) SST (sea surface temperature) data for the Indian Ocean from January 1945–December 2003, with each component resulting from the decomposition being analyzed and discussed. On a basin-wide scale, the zonally averaged heat flux in the Indian Ocean can be divided into three latitudinal zones: tropical (6°N–15°S), subtropical-mid-latitude (15°–40°S)and high-latitude (40°–75°S).The heat flux between the mid- to high-latitude zones takes approximately half a year, and is largely positive from the mid- to high-latitude zones (although negative heat fluxes in the same direction may occur); a similar pattern of heat flux occurs between the subtropical to mid-latitude regions within the second zone. Additionally, there exists a dipole-like SST structure in the tropical Indian Ocean, whose relationship with the Pacific ENSO (El Niño/Southern Oscillation) is closer than that between the ENSO and the Indian Ocean dipole. The correlation coefficient between this dipole-like structure and the ENSO is -0.87, and the pattern is entirely the result of the monsoons in the Indian Ocean, with the correlation between the wind fields of a given month and the SST structure of the subsequent month reaching a coefficient of 0.84. It can be seen that the physical decomposition method is superior to the usual method of using the mean monthly climate and decomposing the anomalies. An REOF (rotated empirical orthogonal function) decomposition of the second component arising from a physical decomposition of the surface wind stress data for the Indian Ocean reveal a subtropical tripole structure.

S1-P3

Transoceanic fluxes in southern Patagonia

Anahí A. **Brun**[1,2], Marcelo Acha[3,4] and Alberto R. Piola[1,2,3]

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The Patagonian continental shelf hosts a diverse community of fish, mollusks, birds and mammals of commercial importance and conservation. The development of these species critically depends on the physical and chemical conditions of the marine environment. The most conspicuous oceanographic characteristic over the southern portions of the shelf is its low salinity presumably originated in oceanic and coastal areas of SE Pacific. The objective of this study is to determine the physical and chemical characteristics of the inflows to the Patagonian continental shelf and their seasonal variability, and the associated planktonic groups. Analysis in temperature-salinity space and historical hydrographic data SE Pacific and SW Atlantic indicate a marked seasonal variability in the physical properties of the surface layers in the western Magellan Strait. These changes are due to the increased continental runoff as a result of melting of continental ice in the warm season. This continental runoff generates 2.5° C temperature inversions in the upper 117 m, which are compensated by a sharp salinity increase. Published results indicate that copepods and amphipods in the region are also distributed in two layers with distinct composition and abundance. Because these zooplankton species serve as food of several species, their distribution might have a significant influence higher trophic levels.

S1-P4

Growth rate and fatty acid composition in the Humboldt Current krill, *Euphausia mucronata*, in the coastal upwelling zone off central Chile

Ramiro **Riquelme-Bugueño**[1,4], Jocelyn Silva-Aburto[2], Celia Ballotta[1], Silvio Pantoja[1,3], Rubén Escribano[1,4], Wolfgang Schneider[1,4] and Pamela Hidalgo[1,4]

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The Humboldt Current System (HCS) is one of the most productive eastern boundary ecosystems of the world ocean. This region is strongly influenced by coastal upwelling that promotes high primary, secondary and fish production. Coastal upwelling is a key process controlling temporal and spatial variability of zooplankton, such as euphausiids (krill). *Euphausia mucronata* is the numerically dominant and endemic krill species of the HCS. This krill species plays a pivotal role in the pelagic food web of the HCS, because it transfers energy/carbon from lower to higher trophic levels. However, vital rates (*e.g.* growth) and nutritional condition (*e.g.* lipids) of this species are poorly understood. We studied the instantaneous growth rate (IGR) from 2011 to 2014 during incubations of living krill. Fatty acid (FA) composition was identified by gas chromatography from frozen samples during 2013-14. Studies were carried out in the coastal upwelling zone off central Chile (~36.5°S) at near seasonal scale. The IGR ranged from -0.66 to 0.38 mm d^{-1}. Higher IGRs were observed during upwelling in austral spring-summer than in the remaining months. Detected FA included c16:0, c16:1ω, c20:5ω (biomarkers of diatoms), c18:1 (biomarker of bacteria), c18:4ω, c22:6ω (biomarkers of dinoflagellates), and c20:1ω and c22:1ω (biomarkers of copepods). Principal component analysis showed significant changes in FA composition between upwelling and non-upwelling periods. Our findings suggest that the coastal upwelling regime impacts *E. mucronata* growth and nutrition by modifying the food web structure that sustains the population during its life cycle.

S1-P5

Submarine Groundwater Discharge for the coastal region in southern Brazil

Karina Kammer **Attisano**[1], Isaac Rodrigues Santos[2], Carlos F.F. de Andrade[1], Mariele Lopes de Paiva[1], Idel Cristina Bigliardi Milani[3] and Luis Felipe Hax Niencheski[1]

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Submarine Groundwater Discharge (SGD) may lead to an important flow of chemical elements from the continent towards the ocean, mainly in regions where there are coastal aquifers, such as the coastal region in southern Brazil (CRSB). This study estimated the SGD for the CRSB by employing natural geochemical tracers (^{223}Ra, ^{224}Ra, ^{226}Ra) in three different meteorological scenarios. After the SGD and its components were estimated by the salt balance, they were associated with the nutrient concentration found in the region, resulting in estimates of the nutrient subterraneous flow to the CRSB. Although there are several nutrient transformation, addition and removal processes along the trajectory of the SGD (continent-sea), the recirculation of sea water is extremely necessary for the maintenance of the subterraneous estuary. This flow is also essential for the increase of the potential of primary production in the surf zone through the SGD. Calculations based on molar ratios (16N:106C) led to the conclusion that the marine discharge of nutrients to the CRSB promotes high productive potential (2800 gCm^{-2} year^{-1}). This must definitely be included in the mass budget of the region since its productive potential is 7 to 32 times higher than the other regions where this estimate was also carried out.

S1-P6

Vertical migrations of copepods in the oxygen minimum zone: Conceptual model approach and it simplication of the bioelement fluxes

Carlos A. **Cantergiani**[1,2], Carol C. González[1], Guillermo Feliú[1,2] and Pamela Hidalgo[1,2]

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Copepods have developed vertical migration strategies, allowing interaction between surface layers, oxygen minimum zone (ZMO, <1mL L^{-1}) and deep sea, participating significantly in the nutrient fluxes of the water column, represented in the proposed conceptual model.

The influence of the OMZ, which is shallow in the northern and deeper in the center-south of Chile, is a determining factor on the abundance and vertical distribution of copepods.

We propose a conceptual model of the interactions between the dominant group of zooplankton in the water column, based on the collection of information published above the vertical migration strategies in the Chilean coast associated with the OMZ. The model is based on these interactions together with the active transport and passive flow of bio-elements.

Theses vertical movements of the OMZ, product upwelling events, is key in determining the vertical distribution of copepods and acquired strategies to interact with the layer of lower oxygen content.

The different vertical migrations developed by copepods interacting with the OMZ has implications sewers, retention and transport of organic matter between the surface layer and these a floor. The model is based on these multiple interactions, where trophic flows are not confined to the pelagic system and/or benthic, but both are part of the same chain biogeochemical processes. The model represents an approximation of the set of biological, physical and chemical interactions that allow us to understand qualitatively bioelements flows and processes in the upwelling zones of the marine environment of the Chilean coast.

S1-P7

Abundance and biomass of live and dead copepods associated with the oxygen minimum zone in northern Chile (23°S)

Carol C. **González**[1], Carlos A. Cantergiani[1,2], Guillermo Feliú[1,2] and Pamela Hidalgo[1,2]

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Zooplankton has great ecological importance due to its key role in pelagic food webs, as well as being essential for biological carbon pump, acting as an indicator of environmental quality and climate variability. Measurements of biomass of dominant taxa, such as Copepod group are a great contribution to quantify energy flows into the higher trophic levels.

The aim of this study is to present an approach to correction biomass estimates copepoda group, whereas there is a dead fraction, which may overestimate the total biomass available.

Seasonal and stratified zooplankton samples were collected monthly during 2010 in Mejillones bay (23°S). The samples were treated with the neutral red technique and identified and counted the organisms of non - living and lived fractions.

During winter, *Acartia tonsa* dominated the surface layer in the dead fraction. Whereas, *Paracalanus* cf. *indicus* were in the OMZ and oxycline layers. In summer, *A. tonsa* dominated in the surface, as in the oxycline.

Biomass estimates from the dead fraction of copepoda group can achieve up to 10% of total zooplankton biomass, whereupon we suggest that biomass estimates this ratio should be considered for more accurate approximations.

S1-P8

The effect of advection on biogenic fluxes and paleo-proxies in the deep South China Sea

Jianfang **Chen**[1], Martin G. Wiesner[2], Hongliang Li[1], Lihua Ran[1], Niko Lahajnar[2] and Ronghua Chen[1]

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In this presentation we will address how advection affect on biogenic particle fluxes in the South China Sea and its significance for paleoenvironment proxies based on results from time-series sediment trap experiments in the deep South China Sea, which were carried out jointly between the Second Institute of Oceanography, SOA and the University of Hamburg, Germany. Our results showed that sometimes higher biogenic particle fluxes was observed in the deep traps (2250-3750m) then those in shallow traps (1000-1200m) in the same sampling periods, which was attribued to advection of biogenic particles formed from other area of upper layer waters. This phenomenon was also supported by a biomarker index U^{K}_{37}. In most cases, sea surface temperature (SST) measured by U^{K}_{37} in settling particulate matter differs from the upper layer remote sensing SST (if there was no advection, two SST curve should be similar), and there was also decoupling of particulate matter U^{K}_{37} signals between upper and deep traps during the same periods, all attributable to the advection of particles. Although U^{K}_{37} temperature derived from settling particles disagrees with remote sensing SST, a good correlation between the sediment U^{K}_{37} temperature and the annual average temperature from the upper layer (30m) in the SCS confirms the empirical linear curve of U^{K}_{37} and SST, and suggests that a long term sediment record (decadal to millennial) may smooth the short term fluctuations of environment paleo-proxies.

S1-P9

Implications of North Brazil Current variations during the last 8000 cal years BP and its role in the paleoclimate on Northeast Brazilian margin

Nancy K. **Taniguchi**[1], Silvia H.M. Sousa[1], Cristiano M. Chiessi[2], Henning Kuhnert[3], Rubens C.L. Figueira[1] and Stefan Mulitza[3]

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We investigated the North Brazil Current (NBC) over the last 8100 cal years BP using a marine sediment core (GeoB 16204-2) collected at Brazilian equatorial continental margin (01°59.75'S, 42°20.30'W, 1211 m water depth). Results of sortable silt mean (), Fe/Ca and Ti/Ca ratios, and the sea surface hydrograph reconstructed from planktonic foraminifera indicate variations of the NBC strength over this period. The core exhibits sedimentation rates varying from 5.5 $cm.kyr^{-1}$ to 43.1 $cm.kyr^{-1}$ with an increase occurring around 5200 cal years BP. The results present patterns of three different intervals. Between 8100 - 5000 cal years BP, high values indicate a strong NBC, high Fe/Ca and Ti/Ca values suggest wetter environment conditions on land and lower marine influence in sediment composition with low $CaCO_3$ values. A transition time between 5000 - 2500 cal years BP was characterized by large fluctuations of, an increase of sedimentation rates and $CaCO_3$ content, and decrease of terrigenous input. The time interval from 2500 cal years BP to the present was marked by the weakening of the NBC with low values and drier conditions in northeast Brazil, low Fe/Ca and Ti/Ca values. For the last 5000 cal years BP, the sea surface hydrograph reconstructed from foraminiferal oxygen isotope and Mg/Ca ratios does not show major changes. We propose that the Holocene variations of the NBC strength were driven by both, changes of the AMOC and meridional shifts of the ITCZ that coincided with changes in humid conditions on Northeast of Brazil.

S1-P10

Nutrient concentrations along the coast of southern Brazil

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The continental supply of nutrients to coastal areas may indicate the contribution of superficial and groundwater that favor high productivity of an area. The southern coast of Brazil at Rio Grande do Sul (RS) is influenced by these processes, so a cruise in January 2013 was conducted in this area (between entre 29º18' S and 49º38' W e 31º51' S and 51º40' W), to identify the distribution of nutrients on the coast. Water samples were collected at the surface and bottom of the water column for the determination of physicochemical parameters and nutrients (nitrate, nitrite, ammonia, phosphate and silicate) in: 1) a transect on the northeastern coast at Torres; 2) a transect along the coastal area in the palaeochannels, and 3) a transect on the southeastern coast at Mostardas near of the Patos Lagoon. The Principal Component Analysis indicates that nutrients on the surface and bottom water at Torres were correlated with the saturation of dissolved oxygen, salinity, nitrite and nitrate, and is inversely correlated with the other parameters. Different characteristics between the surface and bottom water were observed at Osório (30º03' S and 50º02' W). The concentration of nutrients at Mostardas was correlated with suspended material, ammonium, phosphate and silicate. The results showed that the coastal area is influenced by the intensity of continental inputs. Waters near the Lagoa dos Patos are more nutrient-rich waters when compared to other locations.

S1-P11

Nutrient limitation in the subpolar North Atlantic drives mackerel westwards

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The feeding migration of the large and economically important mackerel stock (*Scomber scombrus*) has dramatically expanded westwards, from the Norwegian Sea and towards Icelandic and Greenlandic waters during the last decade. Analysing hydrographic, zooplankton and fish catch data from the joint mackerel surveys between 2007 and 2014, we could not identify simple and general connections between the westward expansion and the hydrographical parameters: temperature, salinity, density and the derived stratification. We have, however, identified region-specific hydrographic limits, like the 5°C near-surface isotherm to the north of Iceland, which mackerel do not appear to cross (zero catches for lower temperatures). Temperature changes can, however, not explain the expansion of mackerel in the Irminger Sea or the zero catches of mackerel in the Iceland Basin to the south of Iceland. The Irminger Sea and Iceland Basin are very different ocean environments, influenced by different water masses and oceanic processes. The subpolar gyre limb in the Irminger Sea is a major source of nutrients for the subpolar Atlantic, and the vigorous vertical convection there induces high primary productivity and zooplankton abundances making this area an attractive feeding region for the mackerel. The subpolar gyre has weakened much since the mid-1990s, allowing warm, saline and nutrient poor eastern waters to spread pole-ward, and the nutrient concentrations and zooplankton abundances in the Norwegian Sea have declined in a similar fashion. We hypothesize that the presently declining nutrient levels in the North Atlantic might be driving the mackerel stock westwards, towards the main nutrient sources.

S2 Posters
Ocean acidification

S2-P1

Assessment of acidification and eutrophication in the coastal waters of Bolinao, Pangasinan, Philippines

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Ocean acidification is becoming a global concern due to its potential effects on marine resources. In coastal areas, an emerging problem is ocean acidicification due to eutrophication resulting from human activities. The coastal water of Bolinao, Pangasinan, Philippines has become eutrophic due to increased nutrient loading from unconsumed fish feeds in fish cages. Mariculture is a big industry in Bolinao. In over a decade, the area has experienced decreased oxygen levels leading to hypoxia, fish kills, and algal blooms. The decomposition of organic matter from unconsumed fish feeds results not only to high nutrient buildup but also increased CO_2 and acidity in the area. Nutrients (ammonia, nitrate, nitrite, phosphate and silicate), total alkalinity (TA), dissolved inorganic carbon (DIC), pH, dissolved oxygen (DO), aragonite saturation state (Ω_{arg}) and partial pressure of carbon dioxide (pCO$_2$) were measured to determine the combined effect of acidification and eutrophication in Bolinao. Monitoring results have shown an increase in nutrients by 30% to 70% in over a decade. Stratified water during rainy season have resulted in low DO (<5.5) and acidic water (<7.5) with high pCO$_2$ level (>900 µatm). Shallow stations with poor water circulation have shown undersaturated aragonite state (< 2.0) and high pCO$_2$ levels of 800 µatm. The eutrophic and acidified coastal waters of Bolinao are already affecting the seagrass and coral reef ecosystems in the area.

S2-P2

End-to-end assessment of ocean warming and acidification on fisheries: From experiments and models to economic and social impacts

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An assessment of the potential biological impacts and economic consequences of ocean warming and acidification is needed for sustainable ocean resources management. Here, we use new theory, observations, experiments and modelling to quantify (in terms of catches, monetary value and equivalent jobs) the combined effects of acidification and warming on commercial fish and shellfish under different CO_2 emission scenarios. The UK is used as a case study area but the methods and key messages will be transferable across a broad range of settings. Incorporation of combined acidification and warming experimental data into the model scenarios consistently resulted in greater modelled changes than use of warming data alone. Shellfish species were impacted the most across the scenarios tested. This translates in a decrease in total potential landings in most UK administrative areas and particularly for the small vessels fleet. We also calculate the economic equivalent direct and indirect impacts in terms of income and jobs when using the results from this work projection considering the total fisheries related economy. The economic and social impacts could be further exacerbated in communities with economies highly dependent on fishing which are considered particularly vulnerable if there is a lack of a diversified economy.

S2-P3

Impact of ocean acidification on marine clownfish sperm behaviour and fertilization of *Amphiprion sebae*

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Atmospheric elevated CO_2 levels cause ocean acidification. These levels can potentially change the ocean pH upto 0.3 units at the end of this century. Reduced pH may have severe effects on the physiology and evolutionary consequences of marine organisms however experimental studies remain scare, in particular concerning fish. The adult fishes are not affected by reducing pH whereas sperm and larval stages are potentially more sensitive. In this present study the effects of ocean acidification on sperm (sperm motility, percentage of sperm motility and viability sperm) and fertilization behaviour of clownfish *Amphiprion sebae* were assessed. We found no significant effects of decreased pH on sperm behaviour, whereas we found significant change in fertilization behaviour. This finding proposes that levels of ocean acidification significantly disadvantage of clownfish.

S2-P4

A 12 ka history about changes in deep ocean carbonate chemistry and its effects on foraminiferal tests

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Changes in pCO_2 directly affect the seawater carbonate chemistry and consequently marine calcifying organisms. Foraminifera are important unicellular shelled microorganisms, composed generally of calcite or aragonite. Foraminiferal shells have been widely used on studies assessing the past history of the ocean and the climate system, since they record seawater conditions and show a high preservation potential on sediments. However, these organisms are affected by acidic environments due to the dissolution of its $CaCO_3$ tests. The effects of changes in carbonate chemistry over foraminifers are archived in the geological record. The partial dissolution of the tests affects its weight, density and morphological characteristics. Here we evaluate the effects that changes in the carbonate chemistry had over foraminiferal tests via the *Globigerina bulloides* dissolution index - BDX. This index was applied in a marine sedimentary core (GeoB6308, 39.30°S/53.97°W/3620m water depth) that comprises the deep seawater history of the last 12 ka BP. We were able to determine how the acidic waters can affect foraminifera tests ranging from corrosive waters, during the Holocene, to very corrosive waters during the late glacial. The results allow us to evaluate how sensitive the foraminiferal tests are to changes on seawater carbonate chemistry.

S2-P5

Effects of seawater acidification on *Diopatra neapolitana* (Polychaete, Onuphidae) performance: Biochemical and regenerative capacity responses

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Changes in atmospheric CO_2 concentrations and, consequently, ocean acidification, together with changes in seawater chemistry, are likely to have a large impact on marine ecosystems. Much of the current research concerning the consequences of ocean acidification has been limited to organisms dependent on the availability of carbonate ions in seawater, especially bivalves. Nevertheless, many marine organisms do not rely on calcium carbonate structures, such as most of the polychaete species that might also be affected by seawater acidification. Essentially due to their life-history characteristics, as well as their relatively rapid response to pollution, several studies have been using Polychaetes as sentinel species for anthropogenic (*e.g.* organic and inorganic contamination) and natural stresses (*e.g.* salinity shifts). However the effects of ocean acidification on

these organisms are almost unknown. Thus, in the present study, the effects of pH reduction were studied in the polychaete *Diopatra neapolitana*, using the tissue regenerative capacity and biochemical changes as biomarkers. The results obtained revealed that individuals exposed to lower pH levels exhibited lower capacity to regenerate their body, in comparison with control organisms. This study also evidenced that seawater acidification induced oxidative stress in *D. neapolitana*. Thus, the present work validated the use of *D. neapolitana* as a test organism in laboratory-based bioassays, but also as an adequate bioindicator species to pH reduction in the environment.

S2-P6

How life history influences the responses of the clam *Scrobicularia plana* to the combined impacts of pH decrease and carbamazepine

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Recent reports revealed that increases in water acidification are predicted to occur in the next 100 years and several studies have shown that the oceans have already experienced a 0.1 pH unit reduction since pre-industrial periods. According to different studies, by 2100 pH is expected to decrease approximately 0.4 units. Aside from ocean acidification, there is an increasing concern about the large number of emerging pollutants present in aquatic environments, such as pharmaceutical drugs. While an increasing amount of data has been published on the occurrence of pharmaceuticals in the environment, information on their effects on aquatic organisms is still scarce. Nevertheless, the magnitude of the presence of these pollutants in the environment is not well known and there is a lack of information about the potential environmental risks associated with these pollutants, namely under a climate change scenario. In the present study, the bivalve *Scrobicularia plana*, collected from two contrasting areas (pristine location and Mercury contaminated area), was selected to assess the biochemical alterations imposed by pH reduction, carbamazepine (an antiepileptic drug) and the combined effect of both stressors. The effects on oxidative stress related biomarkers after 96h (acute assay) and 28 days (chronic assay) revealed that both stressors induced alterations on clams, with greater impacts for the clams from the contaminated area.

S2-P7

Biochemical and metabolomic alterations in the invasive clam *Venerupis philippinarum* when exposed to salinity changes

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Salinity is one of the dominant environmental factors affecting marine bivalves but little information is available on the responses of aquatic organisms to such natural alterations. The ebb and flood of the tide, combined with fresh water inputs from rivers or heavy rainy events, and with extremely dry and hot seasons, can dramatically alter water salinity. Therefore, the salinity of a certain environment can restrict the spatial distribution of a given population, which is especially important when assessing the spread of an invasive species into a new environment. In the present study, the main objective was to understand how the invasive clam Venerupis philippinarum copes with salinity changes through biochemical and metabolomics analyses. The results showed that V. philippinarum presented high mortality at lower salinities (0 and 7 g/L) but tolerated high salinities (35 and 42 g/L). The quantification of ionic content revealed that, clams had the capacity to maintain ionic homeostasis along the salinity gradient, mainly changing the concentration of Na, but also with the influence of Mg and Ca. Glycogen and glucose increased with increasing salinity gradient. 1H Nuclear Magnetic Resonance (NMR) spectra of clam aqueous extracts revealed different metabolite profiles at 7, 28 and 42 g/L salinities, thus enabling metabolite changes to be measured in relation to salinity. The results showed that clams under salinity associated stress can alter their biochemical mechanisms, such as increasing their antioxidant defenses, to cope with the higher oxidative stress resulting from hypo and hypersaline conditions.

S2-Posters

S2-P8

Effect of elevated carbon dioxide concentrations on the growth of estuarine bivalve *Macoma balthica* from the Baltic Sea

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Ocean acidification is one of the most threatening phenomenon in the marine environment. Carbon dioxide concentration in atmosphere is predicted to rise continuously in the next decades and to have serious consequences at various levels of biological organisation going from species and populations to changes in ecosystems. The most endangered by water pH decline are calcifying organisms which suffer from lower biomineralization rate and shell dissolution.

In our experiment the impact of elevated carbon dioxide concentrations in water on the Baltic clam *Macoma balthica* was studied using four CO_2 levels: 400 ppm (control), 1000 ppm, 2000 ppm and 10000 ppm corresponding roughly to pH 7.7, 7.3, 7.0 and 6.3, respectively *i.e.*, within a wide range of CO_2 concentrations predicted in the future. One feeding regime was applied to all treatments under stable salinity (7.0) and temperature (10°C) conditions. Organisms were collected in five replicates at time points: 4 weeks before the experiment (acclimation period), after acclimation (time 0) and then 1, 2, 4, 6 and 8 weeks after CO_2 increase. Shell growth rate was determined using fluorochrome marking *i.e.*, 250 mg dm^{-3} calcein shell staining for 24 hours before the experiment. Internal calcein mark deposited in shell during the exposure was measured using average 200 µm cross-cut sections incorporating the maximum growth axis of the shell embed the in epoxy resin under an NIKON fluorescence microscope exciting at 460–490 nm.

S2-P9

Long-term effects of ocean acidification on free-living coralline algae

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Mäerl beds are important carbon sinks and sensitive habitats to ocean acidification (OA). However, it is still unclear how a decrease on the ocean's pH will affect these ecosystems in a near future. Some of the inconsistencies found among OA experimental studies are due to differences in methodology and time of exposure. The objective of this study was to measure the effect of OA on the metabolism and calcification of the most common mäerl species from southern Portugal, *Phymatolithon* sp. Algae were maintained in aquaria for twenty months at three different pCO_2 levels. Primary production and calcification responses to elevated pCO_2 were investigated at different light levels and in dark conditions. Both photosynthesis and calcification rates were affected by the CO_2 concentration and the time of exposure. Both the photosynthetic and the calcification rates of algae exposed to high CO_2 increased during the first 11 months of the experiment at the mesocosm. However, at the end of 20 months the pattern was reversed and control algae showed higher photosynthetic and calcification rates and higher accumulated growth. *Phymatolithon* sp. was able to acclimate to an intermediate pCO_2 level of 550 ppm with no significant metabolic effects, but after 11 months at 750 ppm the algae were not able to compensate the deleterious effect of OA. We found that factors such as high irradiance and time of exposure aggravate the negative effects of ocean acidification on these algae.

S2-P10

Effects of seawater acidification on a coral reef meiofauna community

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Despite the increasing risk that ocean acidification will modify benthic communities, great uncertainty remains about how this impact will affect the lower trophic levels, such as members of the meiofauna. A mesocosm experiment was conducted to investigate the effects of water acidification on a phytal meiofauna community from a coral reef. Community samples collected from the coral reef subtidal zone (Recife de Fora Municipal Marine Park, Porto Seguro, Bahia, Brazil), using artificial substrate units, were exposed to a control pH (ambient seawater) and to three levels of seawater acidification (pH reductions of 0.3, 0.6 and 0.9 units below ambient) and collected after 15 and 30 days. After 30 days of exposure, major changes in the structure of meiofauna community were observed in response to reduced pH. The dominant major meiofaunal groups showed divergent responses to acidification. Harpacticoida and Polychaeta densities did not show significant differences due to pH. Nematoda, Ostracoda, Turbellaria and Tardigrada exhibited their highest densities in low-pH treatments (especially at the pH reduction of 0.6 units, pH 7.5), while harpacticoid nauplii were strongly negatively affected by low pH. This community-based mesocosm study supports previous suggestions that ocean acidification induces important changes in the structure of marine benthic communities. Considering the importance of meiofauna in the food web of coral reef ecosystems, we should be warned of the potential risk to higher trophic levels if degradation of reefs due to ocean acidification extends to this resource.

S2-P11

Response of bacterioplankton interaction to acidification in the Arctic Ocean revealed by phylogenic molecular ecological networks

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The influences of ocean acidification on the ocean pelagic ecosystem was tested by so far the largest CO_2 manipulation mesocosm study (European Project on Ocean Acidification, EPOCA), performed in Kings Bay (Kongsfjorden), Spitsbergen. The bacterial diversity was investigated using DNA fingerprinting, clone library analysis and high-throughput sequencing of bacterioplankton samples. Our data revealed that general bacterial diversity, taxonomic richness and community structure were influenced by the variation of productivity during the time of incubation, but not the degree of ocean acidification. The phylogenic molecular ecological networks (pMENs) which based on random matrix theory (RMT) showed the nodes and connectivity of microbial community decreased along the increase of pCO_2 concentration. Our results indicated the elevated pCO_2 significantly reduced the interaction among the microbes in the Arctic Ocean, which suggested an instable ecosystem under a high pCO_2 concentration. In addition, the topological structures of the phylogenic molecular ecological networks significantly correlated with biological and chemical variables. Our study suggests that ocean acidification affects the development and interaction of bacterial assemblages and potentially impacts the ecological function of the bacterioplankton in the marine ecosystem.

S2-Posters

S2-P12

Sparus aurata and *Argyrosomus regius* early life stages responses to ocean warming and acidification

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Early life stages of many marine organisms are being challenged by rising seawater temperature and CO_2 concentrations, but little is known about the capacity of fish early life stages to tolerate future ocean conditions. Here we investigated a comprehensive set of biological responses to future predictions of ocean warming (+4ºC) and acidification (ΔpH=0.5) of the larvae of two commercially important teleosts seabream (*Sparus aurata*) and meagre (*Argyrosomus regius*).

Warmer temperature and hypercapnia elicited a decrease in hatching success (by 14.3-26.4%) and larval survival (by half) of both species. The growth rates of *S. aurata* larvae were significantly lower (18.5-30.8%) under hypercapnia. Moreover, the incidence of total body malformations in seabream larvae significantly increased (more than tripled) under warmer and hypercapnic conditions. Concomitantly, larval behaviour of both species was significantly affected, with decreased swimming duration, orientation frequency and reduced capture success of prey under acidification. It is worth nothing that, although the attack rates of larvae of both species was similar among treatments, capture success tended to increase with warming and decrease with hypercapnia. These morphological impairments and behavioural changes are expected to affect larval performance and recruitment, and further influence the abundance of fish stocks and the population structure of these commercially important fish species.

S2-P13

Variations of AT, CT and pH in Indian Austral Ocean between 2005 and 2010 in response to cooling and evaporation

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The impacts of ocean acidification on seawater chemistry and marine organisms have already been measured in several regions around the world, as pH drops began to be known. However, long-term pH records are still scarce, being mainly available only in the Northern Hemisphere. Yet, polar oceans are particularly affected by this mechanism primarily due to its colder waters. Thus, these high latitude ocean areas are very likely the most fragile of the global ocean. Changes in evaporation-precipitation ratio have also demonstrated to disturb pH. The present work investigated the variations of some carbonate system parameters (AT, CT, pH, SST, SST) due to climate change during austral late summer and spring periods in 2005 and 2010. Underway carbonate parameters, temperature and salinity data from the MINERVE program were used to investigate the variations of the carbonate system along the cruise tracks between Hobart (Australia) and the French Antarctic base Dumont d'Urville. Results show a SST elevation (0.66 – 1.71°C) related to the warming of the atmosphere, causing an elevation of AT (6.4 – 7.7 µmol kg^{-1}) and SSS in almost all regions of the studied area. Cooling (0.82 – 0.93°C) and freshening (0.023 – 0.064) of the sea-surface layer was observed primarily during late summer in the southernmost Antarctic zone as a result of fresher and colder water from ice melting, enhancing oceanic CO_2 uptake and lowering pH (from -8 10^{-3} pH to -32 10^{-3} pH). This work corroborates with previous ones and highlights the importance of continuing pH measurements through Austral Ocean.

S2-P14

Effects of seawater acidification on a coral reef Nematoda community

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Despite the increasing risk that ocean acidification will modify benthic communities, great uncertainty remains about how this impact will affect the lower trophic levels, such as members of the meiofauna and of the Nematofauna. A mesocosm experiment was conducted to investigate the effects of water acidification on a phytal Nematofauna community from a coral reef. Community samples collected from the coral reef subtidal zone (Recife de Fora Municipal Marine Park, Porto Seguro, Bahia, Brazil), using artificial substrate units, were exposed to a control pH (ambient seawater) and to three levels of seawater acidification (pH reductions of 0.3, 0.6 and 0.9 units below ambient) and collected after 15 and 30 days. The preliminary results showed that after 30 days of exposure, major changes in the structure of Nematoda community were observed in response to reduced pH ($R=0.443$, $p=0.002$). For now, 48 genera were identified. The dominant genera were Chromadorella (19.13%), Spilophorella (15.36%), Viscosia (7.7%), Euchromadora (6.34%), Chromadorita (5.24%), Acanthopharynx (4.43%), Paracanthonchus (4.23%) and Acanthonchus (4.03%). This community-based mesocosm study also supports previous suggestions that ocean acidification induces important changes in the structure of marine benthic communities, however, the complete identification of samples will enable a more detailed multi and univariate analyses and discussion on Nematoda specie-specific sensibilities.

S2-P15

Effect of ocean acidification in the ecophysiology and ultrastructure of *Halodule wrightii* Ascherson – An evaluation in a tropical mesocom

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Ocean acidification is among the main stressors threating marine biodiversity in this century. The aim of this work was characterize the effects of lower pH and high CO_2 concentration on the physiology, anatomy and ultrastructure of the seagrass *Halodule wrightii*. Mesocosm with natural irradiance, reproducing general environmental factors observed in southwester Atlantic tropical seagrass bed, where utilized in a 30 days evaluation, handling different concentrations of CO_2, decreasing pH 0.3 unit (-0.3), 0.6 unit (-0.6) and 0.9 unit (-0.9), which represented the simulation of an atmosphere containing 650, 1350 and 3390 ppm CO_2. Photosynthetic efficiency (αETR) and effective quantum yield Y(II) was higher under acidified condition concentration of CO_2 (-0.6 and -0.9), when compared with lower CO_2 concentrations. Increases in CO_2 availability compensated the expected stress related with the pH reduction, feed the photosynthetic metabolism, increasing the evaluated physiological parameters. The anatomy and ultrastructure of the leaves of the cultivated specimens in the control as well as the treatments did not demonstrate qualitative alterations. Quantitatively, it was observed cross-sectional area and width of the leaves greater in the -0.9 treatment. According to the literature, such modification in leaf structure can be attributed to the influence of CO_2 on cell division and expansion. Our results reinforce the importance of these blue carbon species as foundation groups mitigating or even helping in remediation of climate change in coastal zones.

S2-P16

The submarine groundwater process, the biological pump and the CO_2 fluxes on the Brazilian southeastern and southern shelf

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Studies of the Brazilian southeastern and southern coastal shelf are important, mainly in the south, where the influence of submarine groundwater on the ocean is very evident. This phenomenon is relevant because contributions of trace elements, which may influence primary productivity and changes in the pressure of CO_2 diffusion to the ocean, aspects that may feedback the local atmospheric circulation and possible climate changes. Therefore, an oceanographic cruise is planned by the INCTMarCOI project (CNPQ 565062/2010-7) for January 2015 in that area. It aims at verifying the influence of discharge and advection processes of submarine groundwater on the coastal area and at assessing the amount of atmospheric carbon dioxide biologically transferred from the surface to the bottom of the ocean, mainly by the biological pump. Sampling will be carried out in three transects (*Albardão*, *Torres* and *Santa Marta*) with 6-7 stations on the horizontal profile and 2-5 stations on the vertical one, in depths that range from 20 to 1500 m. The following parameters will be analyzed: physico-chemical ones, nutrients, chlorophyll *a*, dissolved and particulate trace metals, ^{222}Rn, ^{223}Ra, ^{224}Ra, ^{226}Ra and ^{228}Ra, particulate fractions of organic carbon, $\delta^{13}C_{COT}$, ^{234}Th, ^{238}U and Po and partial pressure of CO_2 in air and water. The analyses of trace metals, total organic carbon, $\delta^{13}C_{COT}$ and the granulometric one will also be carried out for sediments. This study should contribute to the understanding of the processes of groundwater advection, the biological pump and the carbon flux in the areas under study.

S2-P17

Acidification of Europe's seas: An overview based on the European Climate Adaptation Database

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In April 2013 the European Commission adopted the EU strategy on adaptation to climate change which aims at making Europe more capable to face climate change by reducing the vulnerability of its sectors, systems, people and assets. It sets out a framework and mechanisms for taking the EU's preparedness for current and future climate impacts to a new level.

Based on the European Climate Adaptation Database the poster presentation provides an overview of publications, reports, research and knowledge projects deal with the acidification of Europe's seas. It also presents anthropogenic drivers, pressures, state, impacts and responses due to the acidification of European seas, in the context of climate change.

The researches on the acidification of Europe's seas show that the average surface pH of the Black Sea is substantially higher than that of the Baltic and Mediterranean Seas. Differences in surface pH between these seas are largely explained by differences in carbonate ion concentrations. The relative change in the pH is slightly more in the Baltic Sea where the carbonate ion concentration is lowest and it is slightly less in the Black Sea, where carbonate ion concentrations are highest. Well before the end of the century, surface-waters of the Baltic Sea could become corrosive to all forms of calcium carbonate whereas there is no risk of this occurring in the Black Sea and Mediterranean Seas before 2100. The people most vulnerable to the impacts are Arctic indigenous people who depend critically on fisheries for their diet and income.

S3 Posters
Changing ocean chemistry: From trace elements and isotopes to radiochemistry and organic chemicals of environmental concern

S3-P1

Natural and anthropogenic sedimentary organic compounds in the Guajará Bay, an urbanized Amazonian coastal system (Pará, North Brazil)

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Amazonian coastal systems are usually associated with pristine waters, however, increasing irregular urban occupation of the hydrographic basins, disposal of untreated wastes and sewerage deficiencies have placed these environments among vulnerable areas to contamination and waterborne diseases. The Guajará Bay is part of the Amazon delta, a fluvial-dominated estuarine system in North Brazil that receives drainage from the Belém Metropolitan Region, the most populated Brazilian northern coastal city. We investigate a range of natural and anthropogenic derived organics that can be adsorbed into particles and accumulated in sediments. Surface intertidal sediments and sediment cores from the Guajará Bay were analysed for polycyclic aromatic hydrocarbons (PAHs), mangrove derived steroids, fecal steroids, phosphorus fractionation, and chlorophyll *a*. Ancillary data (total organic carbon, granulometry and hydrochemical parameters) were also examined. Predominance of high molecular weight PAHs indicated pyrolitic sources. Specific PAH ratios suggested that the area is also under anthropic contamination originated from fossil fuel combustion. High concentrations of fecal steroids and total phosphorus concentrations were also found. Although the area is under strong hydrodynamics, which presumably promote dispersion and depuration, our data confirmed sewage contamination comparable to urbanized coasts worldwide. Contribution from mangrove was highlighted by high concentrations of sitosterol and prominent m/z signals of β-amyrinyl and long chained n-alkanol (C_{30}). According to Brazilian legislation, PAH concentrations appear to be below the levels considered hazardous for dredging. A long term monitoring programme is needed to properly assess the environmental quality of the Guajará Bay. UFPA/Capes, INCT Amb Tropicais.

S3-P2

Fingerprints of centennial climate change on ocean biogeochemistry

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Alteration of the ocean's physical and biogeochemical state during the Anthropocene is occurring at unprecedented rates. To assess future impacts and their permanence, we rely on Earth System Models of coupled carbon-climate forced with a range of scenarios for projected emissions and resulting concentrations. In this study, we employ a mitigation scenario in which the projected Representative Concentration Pathway (RCP) forcings for RCP8.5 are applied out to 2100, and then reversed over the course of the following century in a fully coupled carbon climate earth system model, to assess the commitment to legacy effects of anthropogenic CO_2 and other radiative forcings on ecosystem functioning and nutrient cycles in the ocean. We find that while global scale surface phosphate and surface pH are largely reversible, remnants of climate change linger on others such as silicate substantively, and on all variables regionally, attesting to the non-linear feedbacks and interactions of climate, CO_2 and ocean biogeochemistry. We further explore the mechanisms underlying these fingerprints of climate change by ocean basin, finding large differences in the Atlantic and Pacific. We conclude that even under drastic but plausible mitigation strategies, irreversible changes can occur regionally, and in some cases globally, on centennial timescales.

S3-P3

Land-sea boundary as a reference for analysis of environmental changes: Sinking particle fluxes of metals and organic matter in a mesotrophic pristine coastal system

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The pristine and mesotrophic Ria of Barqueiro (NW Iberian Peninsula, North-East Atlantic) is a paradigmatic ria (non-upwelling) where the sinking particle fluxes are not a direct result of upwelling (offshore ria) or continental loads (low river flow). This equilibrium may be disturbed by climatic changes. The magnitude of vertical fluxes of particulate metals (Al, Cd, Co, Cr, Cu, Fe, Ni, Pb, V and Zn), as well as POC, PON and Chl-*a*, were evaluated at the middle of the ria at 20m depth (Jan/08 to Jan/09), by means of a multi-trap anchored to the sea-bottom (24h period). Vertical metal fluxes ranged from 0.02-3.19 $gAl \cdot m^{-2} \cdot d^{-1}$, 0.65-3.23 $\mu gCd \cdot m^{-2} \cdot d^{-1}$, 0.01-0.50 $mgCo \cdot m^{-2} \cdot d^{-1}$, 0.10-18.28 $mgCr \cdot m^{-2} \cdot d^{-1}$, 0.18-18.28 $mgCu \cdot m^{-2} \cdot d^{-1}$, 0.10-1.58 $gFe \cdot m^{-2} \cdot d^{-1}$, 0.10-10.07 $mgNi \cdot m^{-2} \cdot d^{-1}$, 0.07-4.36 $mgPb \cdot m^{-2} \cdot d^{-1}$, 0.06-2.95 $mgV \cdot m^{-2} \cdot d^{-1}$ and 0.49-18.52 $mgZn \cdot m^{-2} \cdot d^{-1}$; while POC was 152-1311 $mg \cdot m^{-2} \cdot d^{-1}$. The obtained results also showed a high seasonal variability of the studied metals. Scenarios of (i) increased rainfall and (ii) north wind prevalence suggest a rise in the sinking of Al, Cu, Ni and V (river) or Co, Fe, and Pb (upwelling), respectively. This study was supported by MITOFITO project (MINECO: CTM2011-28792-C02, Spain). Dr. Ospina-Alvarez acknowledges the financial support from AXA Research Fund (Paris, France).

S3-P4

Ra isotopes as tracers of iron (Fe) sources supplying the phytoplankton blooms under the ice in the Arctic Ocean

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The Arctic Ocean is a highly sensitive region, and is profoundly affected by climate change. Reduction in ice thickness and sea ice cover of the Arctic Ocean results in an increase in the length of the ice melt season and an overall increase in light availability, and hence, an increase in phytoplankton growth. Ice-free continental shelves, such as those found in parts of the Chukchi Sea, frequently experience intense seasonal blooms of phytoplankton owing to their favourable micro and macro-nutrient and light conditions. The aim of this current research work is to use radium isotopes as tracers to investigate the inputs of Fe to the Chukchi Sea and determine its source strength. This study form part of a large program conducted by National Science Foundation called "Study of Under-ice Blooms in the Chukchi Ecosystem (SUBICE)". Samples were obtained during a research cruise between May 13th to June 24th, 2014, on board the U.S.C.G.C. *Healy.* The use of Ra isotopes will shed light into the role of iron in the formation of large phytoplankton blooms that occur beneath the sea ice in the Chukchi Sea. In addition, natural Ra isotopes are also used to trace mixing rates of water masses, and will be linked to dissolved and dissolvable Fe, and to Fe ligand data. These observations will be related to nutrients, inorganic carbon and chlorophyll distributions. The short-lived radium isotopes were counted on a Radium Delayed Coincidence Counter (RaDeCC). ^{226}Ra and ^{228}Ra activities were determined by gamma ray spectrometry.

S3-P5

IGMETS: Assessing global oceanic changes one time-series at a time

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The natural biogeochemistry and ecosystem dynamics of the ocean vary across a range of temporal and spatial scales. The added anthropogenic forcing results in unprecedented and often times unpredictable changes to the marine environment. Biogeochemical ocean time-series have recently taken on renewed importance as their sustained, high temporal frequency measurements can help distinguish between natural and human-induced variability.

The International Group for Marine Ecological Time Series (IGMETS) is building a compilation of >200 ship-based marine ecological time-series to detect changes in some of the most important biological and biogeochemical parameters. The main product of IGMETS will be in the form of a comprehensive, integrated report published under the auspices of IOC-UNESCO, with additional information available through online data repositories and interactive maps. The estimated release date of this report is Fall 2015.This effort seeks to understand, from a regional and global perspective, the changes our ocean has undergone, identify potential drivers, and translate what they mean for local ecosystems. In the future IGMETS also aims to improve positive synergies among ship-based, biogeochemical time-series, facilitate data exchange, and promote related research proposals. The initiative also highlights the need to use consistent and inter-comparable sampling and analytical protocols to be able to bring together datasets from different time-series.

By pooling together time-series resources, it will be possible to compile an assessment of changing biogeochemistry and ecosystem dynamics at a global scale, and understand how such changes can impact important ocean processes such as species distribution patterns.

S3-P6

Guanabara Bay organic matter flux and its influence in the adjacent continental shelf

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Eutrophic estuaries play an important role in the transport of organic matter (OM) from continents to the ocean. Guanabara Bay (GB) is an eutrophic estuarine system located in Rio de Janeiro, the second largest metropolitan and industrial area in Brazil. This study aims to evaluate the transport and distribution of organic materials from natural and anthropogenic origin between GB and the adjacent coastal area. For this we are sampling water over 25 hours in winter and summer time from three different depths (1, 5 and 12 m), using an *in situ* McLane pump, at a single station strategically positioned in the bay (22º 57.082' S 43º 07.465' W). Measurements included particulate organic carbon (POC), particulate nitrogen (PN), $\delta^{13}C$ and $\delta^{15}N$, fatty acids and sterols in suspended particulate matter (SPM). Preliminary results for the winter time sampling shows values in a range of 0.04 to 0.18 mgN L^{-1} for PN; 0.25 to 1.47 mgC L^{-1} for POC. The C/N ratio varies 6.4 to 10 evidencing a dominance of marine phytoplankton source of OM.

S3-Posters

S3-P7

Biochemical and metabolomic alterations in the invasive clam *Venerupis philippinarum* when exposed to salinity changes and Arsenic contamination

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Anthropogenic pressure combined with natural changes often imposes multistress situations to organisms. Salinity and persistent inorganic elements is such an example. Nevertheless most studies evaluate the effects of a single stressor. Under a climate change scenario alterations in seawater salinity are predicted, which results from warmer temperatures associated with drought periods and extreme rainy events. Moreover, salinity is one of the most important environmental factors affecting bivalves. Although the aquatic geochemistry, bioaccumulation and toxicity of As have been the focus of much research, revealing impacts of this metalloid on bivalves and implications to human health, information regarding the combined effect of As and salinity on bivalves is still scarce. Furthermore, studies on As toxicity are mostly based on compartmentalized information regarding alterations imposed to organisms and comprehensive approaches are seldom used. Thus, this study aimed to evaluate the ability of the invasive clam *Venerupis philippinarum* to cope with a range of salinities that may occur under a climate change scenario, associated with the presence of environmentally relevant concentrations of As. Clams were submitted to 5 salinities x 3 as concentrations. The combined effects of the two stressors on clams were assessed by biochemical, physiological and also by metabolomic approaches. The analysis of the results allowed estimating the impact of these two stressors on *Venerupis philippinarum* in natural systems.

S4 Posters
Regional models for predictions of climate change impacts: Methods, uncertainties and challenges

S4-P1

Scaling up experimental ocean acidification and warming research: From individuals to the ecosystem

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Understanding long-term, ecosystem-level impacts of climate change is challenging because experimental research frequently focuses on short-term, individual-level impacts in isolation. We address this shortcoming first through an inter-disciplinary ensemble of novel experimental techniques to investigate the impacts of 14-month exposure to ocean acidification and warming (OAW) on the physiology, activity, predatory behaviour and susceptibility to predation of an important marine gastropod (*Nucella lapillus*). We simultaneously estimated the potential impacts of these global drivers on *N. lapillus* population dynamics and dispersal parameters. We then used these data to parameterise a dynamic bioclimatic envelope model, to investigate the consequences of OAW on the distribution of the species in the wider NE Atlantic region by 2100. The model accounts also for changes in the distribution of resources, suitable habitat and environment simulated by finely resolved biogeochemical models, under three IPCC global emissions scenarios. The model projected significant large-scale changes in the distribution of *Nucella* by the year 2100 that were exacerbated by rising greenhouse gas emissions. These changes were spatially heterogeneous, as the degree of impact of OAW on the combination of responses considered by the model varied depending on local environmental conditions and resource availability. Such changes in macro-scale distributions cannot be predicted by investigating individual level impacts in isolation, or by considering climate stressors separately. Scaling up the results of experimental climate change research requires approaches that account for long-term, multi-scale responses to multiple stressors, in an ecosystem context.

S4-P2

Ocean climate projections downscaled for the Arabian Gulf

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Climate change projections into the 21st century from CMIP5 models are downscaled for the Arabian Gulf using a regional high-resolution model (ROMS). Results show that the local ocean physics are realistically represented. We show here the model skills required to sustain the anthropogenic trends and variabilities derived from the climate projected global scenario and its high-resolution local impacts along the 21st century. Local ocean climate change differences relative to two different impact scenarios (21stC and RCP8.5) are examined. Results show changes in the seasonal variability of temperature, salinity and the transport out of the Arabian Gulf system relative to the early and late 21st century. The response of the Arabian Gulf to the large-scale centennial changes in the monsoon regime contributes to changes in the local dynamics processes, though the fresh water flux balance. Thus we have provided the baseline for understanding the local dynamics of the Arabian Gulf and it changes related with *carbon based* climate change, based on the applied regional ocean model formulation forced by large-scale Earth System model climate projections.

S4-P3

Multivariate comparison of modelled and realised changes in fish abundance and distribution in response to climate

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Many modelling approaches have been used to predict changes in fish abundance and distribution under climate change. Approaches range from statistical to process-based, seeking to predict changes on timescales from years to several decades and spatial scales from local to global. Validation of these models at the time (5-15 years) and space (50 to 104 km²) scales that are often most relevant to national and regional fisheries management decision making remains challenging because the field is relatively new in relation to the timescales of change and because suitable data for validating models are sparse. Further, there will be uncertainty about the physical predictions used to force ecological models, so it may not be possible to establish which parts of the process introduce error. Here, we aim retrospective time-series of temperature and primary production for the North Sea to force a dynamic bioclimate envelope model that is used to predict changes in fish abundance and distribution at scales down to 0.5°. Predicted changes in abundance and distribution at the 0.5° scale are compared with annual data from trawl surveys. This is compared with previous validations based on stock assessments, catches and latitudinal shifts in the literature. Preliminary comparisons suggest that large differences between the model and data tend to be observed at the 0.5° scale, with differences decreasing at larger scales. We investigate the reasons for these differences and their consequences for managers seeking to interpret predicted changes in fish abundance and distribution under climate change. This requires computational improvement on the models to be run faster and more massively, so the sources of error can be tracked.

S4-P4

The impacts of climate change on marine environment variation to Japanese scallop growth in Funka Bay, Japan using MODIS and OGCM

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There are much attentions have been focused on the direct and indirect effects of climate changes and marine environment changes on aquaculture, as this may pose a threat to food security and economic growth. The Japanese scallop (*Mizuhopecten yessoensis*) is the most valuable cultured marine shellfish in Japan. Our work integrate Four-dimensional variational (4D-VAR) vertical water temperature data from Ocean general circulation models (OGCMs) and Chl-*a* concentration data from MODIS to develop the three-dimensional (3D) growth prediction model for Japanese scallop in Funka Bay. The results revealed that GAM (generalized adding model) is an effective model to predict the vertical growth of Japanese scallop, the predict results were well verified by *in-situ* data. From the 3D growth distribution maps, we could see that scallop growth varies in different year. Funka Bay is affected by the coastal Oyashio Current from spring. Therefore, from the temperature section at the entrance of Funka Bay, we noticed Oyashio Current variations from 2008 to 2011, the Oyashio Current didn't flow into Funka Bay on 2009. This influence also reflected by 3D scallop growth prediction maps. Also we found the extreme climate events have a significant impact on aquaculture. These information and developed models are vital for research, monitoring and management of sustainability aquaculture systems.

S4-P5

Mode analysis of Indian-Pacific Sea surface temperature anomaly

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1958-2007 SODA monthly-mean marine environment data are used to study the possible mechanisms of Indian-Pacific Ocean Sea Surface Temperature Anomaly (SSTA). Seasonal Empirical Orthogonal Function (S-EOF) is implemented on the Indian-Pacific Ocean temperature anomalies from which the long-term trends were removed. The results show that the SST of equatorial western Pacific and eastern Indian Ocean are low (high), when the SST in western equatorial Indian Ocean and eastern Pacific are high (low). This mode has significant the inter-annual, annual, and decadal variations. Joint mode of the region indicates that the Pacific and the Indian Ocean are mainly controlled by the low frequency ENSO, which leads to abnormal anticyclonic circulation remaining at the equatorial Indian Ocean, bringing the warm water from the eastern Indian Ocean warm pool to western Indian Ocean. This weakens the effect of summer monsoon of Indian Ocean thus causes the synchronized basin-scale SSTA in Indian Ocean throughout the year. In the present study, the primary mode of SST in Indian-Pacific is the low-frequency ENSO mode and consistent mode of Indian Ocean basin; the second mode showed quasi-2a ENSO phase shift mode in the Pacific and dipole mode in Indian Ocean. In the spring, ENSO's phase shifts, which is related with the monsoon shift, increasing the temperature difference between the east and West Indian Ocean. In autumn, dipole temperature distribution appears with east higher than the west, which facilitates the further variation of summer Indian monsoon.

Session 5
Coastal blue carbon and other ocean carbon sinks

Co-Convenors:
Stephen Crooks (ESA Phillip Williams & Associates, USA)
Luis Valdés (Ocean Science Section, IOC-UNESCO)

Plenary Speaker:
Margareth Copertino (Universidade Federal do Rio Grande, Brazil)

Coastal and Marine Ecosystems (CMEs) - such as mangroves, tidal marshes, and seagrass meadows - mitigate the effects of climate change by sequestering carbon dioxide (CO2) from the atmosphere and oceans. CMEs also sequester carbon at significantly higher rates than terrestrial forests and store three to five times more carbon per equivalent area than tropical forests. Some of this excess carbon is exported and subsidises adjacent ecosystems, including open ocean and beach ecosystems. The remaining excess production of CMEs is buried in the sediments, where it can remain stored over millenary time scales, thereby representing a strong natural carbon sink. In addition to burying a fraction of their own production, blue carbon sinks reduce flow, turbulence and attenuate wave action, thereby promoting sedimentation and reducing sediment resuspension, and providing a natural protection from storms and sea level rise, shoreline erosion, etc. This session will combine recent results on blue carbon and other ocean carbon sinks with a social science approach towards the prevention of CMEs degradation caused by land-based activities.

S5 Posters
Coastal blue carbon and other ocean carbon sinks

S5-P1

Space variability of sea-air CO_2 fluxes in the Patagonian Sea: Seasonal biological and thermal effects on CO_2

Lucía C. **Kahl**[1,2,3], Alejandro A. Bianchi[1,3], Ana Paula Osiroff[3], Diana Ruiz Pino[4] and Alberto R. Piola[1,2,3]

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Sea-air CO_2 fluxes (FCO_2) in the Patagonian Sea (PS) were studied using data sets obtained in the period 2000-2006. Based on the PS frontal structures and the thermal and biological contributions to the FCO_2 we present a regional subdivision between distinct regimes. The regional subdivision provides new insights on the processes that control the FCO_2. The interfaces between coastal (CR) and shelf (SHR) regimes are characterized by nearly along-shore fronts. The CR is a source of atmospheric CO_2 (3.1×10^{-3} mol m^{-2} d^{-1}) while the SHR is a CO_2 sink (-5.7×10^{-3} mol m^{-2} d^{-1}). In addition, based on the nature of the processes that drive the FCO_2, the PS can be subdivided between northern (NR) and southern (SR) regions. Both, NR and SR are CO_2 sinks, but the CO_2 uptake is higher in the NR (-5.2×10^{-3} mol m^{-2} d^{-1}) than in SR (-2.4×10^{-3} mol m^{-2} d^{-1}). Seasonality is one of the main sources of variability in the FCO_2. The mean CO_2 capture in austral spring is -6.9×10^{-3} mol m^{-2} d^{-1}, with values as high as -11.1×10^{-3} mol m^{-2} d^{-1} in the NR, while in winter FCO_2 are close to equilibrium, reaching -0.1×10^{-3} mol m^{-2} d^{-1}, in the SR. The analysis of the biological and thermal effects (BE and TE, respectively) in FCO_2 indicates that CO_2 emission regions are dominated by the TE while the CO_2 uptake is dominated by the BE. Our results indicate that the biological pump is the dominant process determining the sea-air CO_2 balance in the PS.

S5-P2

The shelf-life of blue carbon

Tiziana Luisetti[1], Kerry R. Turner[2], Martin Johnson[3], Tim Jickells[3], Julian Andrews[3], Maria G. Palmieri[2], Lucille Paltriguera[1], Silke Kroeger[1], Keith Weston[1], Silvana **Birchenough**[1], Dorothee Bakker[3], Claire Powell[1] and Ruth Parker[1]

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Coastal 'blue' carbon ecosystems (mangroves, saltmarshes, and seagrasses) are important carbon sinks. Current literature limits investigation of the economic value of blue carbon to these ecosystems. In this paper we argue that it is important to extend the consideration of blue carbon to other compartments of the marine ecosystem which are also able to sequester and store carbon. We therefore define blue carbon in its entirety, encompassing coastal blue carbon ecosystems as well as the sediments and the water column of the Shelf Sea and the Deep Ocean ecosystems including their biotic and abiotic constituents. Terrestrial carbon sinks (*e.g.* tropical forests) are protected by international mechanisms. However, despite the evidence that saltmarshes and mangroves (both oceanic and estuarine) store more carbon per hectare than tropical forests, international protection for blue carbon ecosystems is currently not available. Recently, economic incentives such as REDD+ have been investigated for their suitability in the 'blue' ecosystem context. We argue that these mechanisms are more likely to be more applicable to coastal 'blue' carbon ecosystems only. The ecosystems of the Shelf Sea and the Deep Ocean are more complex in terms of stock and fluxes and thus less straightforward to manage, particularly in light of less clear property rights and transnational boundaries. In such cases other instruments, such as international agreements for example, should be considered.

S5-P3

Blue carbon exchanges and storage: Assessing the role of human activities and management implications

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Blue C is the carbon stored in coastal and offshore marine habitats and sediments. Different marine habitats can be characterised on the basis of their potential as carbon sinks, which is their rate of sequestration of atmospheric CO_2 and the length of time of carbon storage. The UK's coast line is occupied by sand dunes, sandy beaches, salt marshes and machair. Current data show that rates of carbon sequestration are high in salt marsh, sand dunes and machair. Statutory protection has slowed down the rate of loss of onshore and coastal margin habitats, but coastal erosion and sea level rise, as a result of climate change, are the main threats. Data concerning the role of offshore habitats as blue carbon sinks around the UK is limited. The UK has also a range of important economic activities on the continental shelf (*e.g.* trawling, dredging and wind farms). These activities also involve sediment disturbance and may interfere with the carbon sink capacity of the marine habitats. Additionally, subsea coarse and sandy sediments, despite lower carbon sequestration rates, cover large expanses of the UK shelf and therefore have the potential to significantly contribute to the UK's overall blue carbon sink. This work assesses the main human activities and Policies in the UK that encourage the sustainable management of coastal and marine ecosystems. Future adaptation of management practices may help in maximising the benefit that blue carbon habitats provide to the UK and should set a guide for other countries with similar marine environments.

S5-P4

Sea-air carbon dioxide fluxes along 35°S in the South Atlantic Ocean and adjacent continental shelves

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Average atmospheric CO_2 reached levels above 400 ppm during 2014. The oceans play an important role in absorbing a significant fraction of the atmospheric CO_2 surplus, but there are uncertainties concerning several oceanic regions, such as the under-sampled South Atlantic Ocean. This study assessed the net sea-air CO_2 fluxes along the 35°S latitude and adjacent continental shelves during 2011 spring and early summer periods. Underway CO_2 fugacity, temperature, salinity and dissolved oxygen measurements were taken continuously from Brazil to Africa. Values of both satellite and discrete *in-situ* chlorophyll *a* concentration along the ship's track were used as support data. The sea-surface CO_2 fugacity (fCO_2^{sw}) showed high variability along the cruise track, with higher values found on the continental shelf and slope regions. All ΔfCO_2^{sw} values showed that a sinking process was occurring during the cruise period, yielding an average net CO_2 flux of -3.1 ± 2.2 mmol m^{-2} day^{-1} (using Wanninkhof 1992). Surface temperature and salinity were the main drivers of fCO_2^{sw} variability and chlorophyll *a* showed little relation to CO_2 data in the whole area. Algorithms for fCO_2^{sw} and normalized fCO_2^{sw} were developed for the South American coastal, oceanic and African regions. Normalized fCO_2^{sw} models presented better results, especially in the western portion (Brazil coast to 20° W) of the study area. This work aims to collaborate with regional and global carbon studies as well as incite new ways in fCO_2 modeling.

S6 Posters
Climate change in the seasonal domain: Impacts on the phenology of marine ecosystems and their consequences

S6-P1

Plankton biogeography and phenology in the Southern Yellow Sea

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The composition and distribution of picoplankton, phytoplankton and zooplankon in the Southern Yellow Sea were studied from the cruises conducted in 2006-2013. The results showed that phytoplankton was dominated by pico-phytoplankton (cyanobacteria). Cell abundance of pico-, nano- and micro-phytoplankton all increased from winter to summer, whereas cell abundance of pico-eukaryote phytoplankton (minor component of the pico-phytoplankton) decreased by around half. The dominant species also changed seasonally in all size spectrums of phytoplankton. Zooplankton density and biomass illustrated significant increases from winter to summer. The dominant mesozooplankton species also changed seasonally. Carbon biomass of nano- and micro- zooplankton was relatively high when phytoplankton biomass was high. Relationships between phytoplankton biomass and environmental factors showed that the onset of the spring bloom was highly dependent on water column stability. Phytoplankton growth was limited by nutrient availability in the summer due to the strong thermocline. The combined effects of P-limitation and vertical mixing in the autumn restrained the further increase of phytoplankton biomass in the surface layer. The low phytoplankton biomass in winter was caused by vertical dispersion due to intense mixing. Compared with the availability of nutrients, temperature did not seem to cause direct effects on phytoplankton biomass and its size structure. Relatively low diversity of zooplankton in summer was related to the high dominance of *Calanus sinicus*, probably due to the strongest effect of the YSCWM in summer.

S6-P2

Causes and effects of hydrography changes in the North Sea from the inter-annual to multi-decadal time scales

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In this on-going project we study seasonal changes, inter-annual variability, decadal regime shifts and multi-decadal trends of hydrography in the North Sea at all depths with a new optimally interpolated hydrography dataset from 1948 to 2013. Our preliminary results indicate multi-decadal temperature changes of 1.5ºC, from surface to near-bottom with strongest trends in the German bight. Negative salinity changes of 1 SU indicate freshening of the surface in the regions of freshwater input from land and Baltic Sea. Driving mechanisms behind these significant multi-decadal trends will be studied with time series of air temperature, precipitation, river outflow and Atlantic circulation intensity and atmospheric indexes like the NAO index. At the inter-annual time scale, preliminary results indicate influence of the NAO only on temperature with strongest signal in the German bight at surface and decreasing with depth. No correlation between salinity and NAO was found. A high correlation between both variables at inter-annual time scale point out a common Atlantic origin for these changes. Since both variables seem uncorrelated with inter-annual changes of the Subpolar Gyre intensity, other candidates for the inter-annual variability, like turbulent meanders of the North Atlantic Current, will be studied. Particular attention will be paid to changes of the seasonal cycle, changes in stratification and mixed layer depth, as important factors for marine organisms. We will revise the hydrographic causes of the known ecosystem regime shifts in the North Sea, as well as bottom-up regulations of the fish stocks and their recruitments.

S6

Seasonal cycles of mesoplankton in different climatic periods in the open coastal waters near Crimea (Black Sea)

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The seasonal dynamics of mesoplankton's abundance from 1960 to 2011 has undergone significant changes. In the 1960s, it was mainly single-humped curve with a maximum in the summer, in the 1990s-2000s there was a sharp decline of number in the summer (up to the disappearance of many species), with a consequent increase in September. In 2009 – 2011s the summer decline was not so fatal, and many species are not affected. Such changes caused by climate variability and the introduction of alien species: the change of meteorological and hydrological conditions in the Black sea in 1980s created favorable conditions for the invasion of warm-water species, including predators. At this time *Mnemiopsis leidyi* A. Agassiz 1865, whose ration are mainly consist from Cladocera and Copepoda, settled in the Black Sea. The larvae of *M. leidyi* were recorded in open coastal waters from late June to late August, when usually observed the development of many mesoplankton species. In the result in June-August the number of mesoplankton decreased to catastrophic. By the end of the 90's some species (many Copepoda and *Noctiluca scintillans*) had a bimodal curve of seasonal dynamics, abundance's peak of Cladocera moved a month later. After invasion of *Beroe ovata* (Chamisso and Eysenhardt, 1821), feeding on ctenophores, the period of mass development of *M. leidyi* was shorter and moved to a later date (mid - late August). As a result, since 2000, plankton community received more favorable conditions for the development, similar to the period of 1960s.

S6-P3

Long term zooplankton variability in a South Atlantic coastal channel and its relationship with climatic indices

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Long term monitoring programmes of marine plankton have shown the potential of plankton communities as indicators of environmental change. Nevertheless, most of the available plankton data comes from monitoring programmes from the Northern Hemisphere. Little is known about plankton variability in the South Atlantic, despite evidence of the vulnerability of the region to climate change. In this study, we gathered almost 18 years of Zooplankton data from the Sao Sebastiao Channel (SSC), located in the Southeast coast of Brazil. The dataset was built from samples collected along the channel from 1995 to 2013 with an annual to monthly sampling frequency. We investigated the relationship between the zooplankton community structure with the following climatic indices: the Southern Oscillation Index (SOI), the Atlantic Meridional Mode (for sea surface temperature [AMM-SST] and wind field [AMM-WIND]) and the Tropical Southern Atlantic Index (TSA). Our analyses showed a significant temporal variability of the zooplankton in the SSC, with an overall decrease in abundance of Acartiidae, Oithonidae and Euterpinidae copepods, and an increase in Temoridae and Clausocalanidae copepods over the studied period. The abundance of various zooplankton groups showed different correlation with the various climatic indices. For instance, Oithonidae copepods showed a negative correlation with SOI and a positive correlation with TSA. Decapod larvae and Temoridae copepods showed a negative correlation with AMM-SST and AMM-WIND. Our analyses suggest changes in the SSC biodiversity are possibly linked with climatic variability, and that SSC zooplankton is a good indicator of climate change impact in South Atlantic biodiversity.

S6-P4

Changing rhythm of stratification on the Northwest Atlantic shelf: Interannual variability and its biological implications

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In the temperate coastal and shelf seas, density stratification follows a seasonal rhythm, in which the water column stratification peaks in summer, destratification occurs in fall, and restratification occurs in spring. This seasonal rhythm is fundamental to a wide range of ecological processes, such as regulating the availability of nutrients and light to surface primary producers. In the Northwest Atlantic shelf region, as freshwater export from the Arctic Ocean becomes more variable with atmospheric warming, the seasonal timing and magnitude of stratification are likely to exhibit large interannual variability with combined effects from ocean warming and freshening. To assess the changing rhythm, we analyze a stratification reanalysis dataset having high spatio-temporal resolution over the period 1978-2010. Different types of rhythm change were resolved using cluster analysis. On the timing and magnitude, temporal patterns exhibit significant year-to-year fluctuations, and spatial divisions display a latitudinal organization over the Northwest Atlantic Shelf, corresponding to the northward increase in freshwater transport and the southward increase in ocean heating. The annual onset of stratification is inversely related to its haline component - stratification develops earlier in years of low sea surface salinity and stronger haline stratification. Conversely, the magnitude of stratification is primarily associated with its thermal component. Over most of the study area, earlier phytoplankton blooms coincide with earlier onset of stratification, suggesting that ocean freshening induced stratification variability affects primary producers, and the timing match-mismatch could potentially have significant consequences for the entire food web.

S6-P5

Juvenile sandeel growth: An individual's physiological and phenological response to climatic warming

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Simulation studies by individual-based modelling can provide a deeper understanding of how an individual's physiology and phenology will respond to climatic warming. Using a bioenergetic individual-based growth model we examined the influence of sea bottom temperature and zooplankton abundance on the growth and survival of juvenile lesser sandeels (*Ammodytes marinus*) in the North-western North Sea. By running the model with real climatic data and variable food availability, exceptionally warm years, like that experienced in 2003, are shown to increase the rate of larval development, resulting in a predicted date of metamorphosis that is significantly earlier than the spring bloom in secondary production. Once in the pelagic environment juvenile sandeel growth displays an inverse relationship with temperature, with the trade off between assimilation and maintenance costs dictating the duration of the feeding season. Significantly, even when food is abundant, an individual experiencing warmer temperature regimes will enter the overwintering life phase earlier due to the increased metabolic costs. Such temporal shifts will increase the likelihood of individual starvation due to reductions in sandeel body condition, with any decline in nutritional value likely to have severe consequences on the breeding success of Scottish seabirds. This study introduces an adaptable modelling framework that can be applied to other commercial fish stocks and sub-populations, providing a basis via which key physiological and phenological questions surrounding the influence of climatic warming can be addressed.

S6-P6

Annual variability in the composition and abundance of the zooplanktonic communities associated with the upwelling zone in Mejillones Bay (23°S), northern Chile

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The Humboldt Current System is one of the most productive marine ecosystems in the world due to ocurrence of upwelling events, and presence of the oxygen minimum zones (<0.5 ml O2 L^{-1}), which affecting the vertical distribution, abundance and diversity of zooplankton groups. In Mejillones Bay (23 ° S) studies have focused on copepods and euphausiids, and very weak or absent in other taxonomic groups of the zooplankton. This study focus is the composition and abundance of the another taxa present, in Mejillones Bay, with escases or inexisting knowlegdes and analyze seasonal variations depending on oceanographic variables to determine if they influence the composition of the zooplankton community, reflected in seasonal changes dominances .

Zooplankton samples were collected monthly using a WP-2 net 200µm in 30-0 m during 2010. Bio-oceanographic information to characterize the physical and biological conditions of the water column was obtained from CTDO and Niskin bottles. Statistical analyzes were performed using the Primer 6 and Sigma Plot software.

We briefly indicate Appendicularians and Chaetognaths are highly abundant during the winter and spring seasons, however, early stages of decapod crustaceans are highly abundant and dominant throughout the year, an exception during late spring, possibly because they leave their pelagic phase. This study can help understand the changes on pelagic community structure as responses to the ENOS cycle and the global climate change.

S6-P7

Cyclopoid copepods in a subtropical coastal area (Ubatuba, Brazil): Growth rates and production

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Zooplankton production in tropical and subtropical waters of the South Atlantic is overlooked and known mainly for adult copepods. Immature stages are known to have higher abundances and different growth rates and the study of such stages is necessary to increase accuracy on production estimates. Since the cyclopoids are a key compartment of tropical pelagic ecosystems, artificial cohort experiments (size classes: 50-80, 80-100, 100-150 and 150-200 µm) were performed to determine growth of 5 taxa of immature cyclopoid copepods (*Dioithona oculata*, *Oithona* spp., *O. plumifera*, *Oncaea* spp. and Corycaeidae). Experiments were conducted in 2009 and 2010 summer and winter seasons and summer 2011 in Ubatuba, southeast coast of Brazil. Temperature, salinity, chlorophyll *a* and pheopigments were controlled during the experiments and correlated with growth rates. Biomass was estimated by length-weight regressions. Growth rates did not show significant seasonal variation and were similar between the cohort classes (except for *Oithona* spp., where *g* was significantly higher in the smaller sized classes). The lowest *g* values were observed for *O. plumifera* (0.08 ± 0.06 d^{-1}), while the highest were presented by *Oncaea* spp. (0.27 ± 0.21 d^{-1}) and *Oithona* spp. (0.25 ± 0.19 d^{-1}). Oithonids displayed the highest abundance, biomass and production. Mean growth (0.27 ± 0.17 d^{-1}), biomass (0.51 ± 0.40 mg C m^{-3}) and production (0.09 ± 0.05 mg C m^{-3} d^{-1}) of immature stages of cyclopoids was similar to other tropical areas. Chlorophyll *a* concentration was not considered a limiting factor on copepod growth in this subtropical region.

S6-P8

Macrophyte community response to the changing water temperature in a shallow brackish water Kõiguste Bay

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Hydrophysical and chemical parameters were recorded with high time resolution during two consecutive summers in a small Bay of Kõiguste (Gulf of Riga, Baltic Sea). Two summers had markedly different weather conditions and water temperatures accordingly. In 2013 water warmed up sooner, but average temperature for July and August was much higher in 2014. Extensive macrophyte community response to the weather conditions were expressed by oxygen regime of the bay. Differences were detected both in diurnal gas regime within the macrophyte crop but also in in the larger temproral and spatial scale.

S7 Posters
Evolutionary response of marine organisms to climate change

S7-P1

Changes in conservation units of some tiger shrimp populations in Southeast Asia

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Population changes in marine organisms at different geological periods can be similar to the effects of varying temperatures brought about by climate change to these marine organisms. These population changes can be known based on different types of markers such as d-loop (mitochondrial DNA) and microsatellite (nuclear DNA). The d-loop is proposed to reflect population changes during sea-level fluctuations of the Pleistocene period while microsatellite reveals later and more current information about a population. Aside from population changes, the statuses of populations as conservation units can be determined too, thus, probable effects of climate change can be related to formation of conservation units. This study amplified d-loop sequences and tested six microsatellites on wild populations of black tiger shrimp from Tanauan, Leyte; Day-asan, Surigao del Norte and Pangandaran, West Java. Fu's F_s and Bayesian skyline plots based on d-loop sequences suggest that Leyte and West Java populations underwent expansion during Pleistocene period while Surigao did not. Migration likely occurred between Leyte and Surigao after Pleistocene period based on genotypes from the six microsatellites. D-loop and microsatellite analyses revealed one management unit (MU). Combined Leyte and Surigao was considered a MU because it passed a test on significant divergence of allele frequencies at nuclear loci. No population was considered as an ESU because there was no reciprocal monophyly based on the resulting phylogenetic tree of the d-loop sequences. Pleistocene sea levels and present-day ocean circulation can be factors that determine how the three populations expand or reduce.

S7-P2

Effects of hypoxia on nitrogen fluxes of *Acartiatonsa* in the oxygen minimum zone of the eastern south Pacific

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Oxygen minimum zones (OMZ) in the eastern boundaries (EB) have been predicted to expand and decrease their oxygen concentrations in the next decades. This oxygen reduction may has unknown implications not only over single species, but also over the ecosystem. One of these consequences may be differenced nitrogen transference among the key players in the trophic chain resulting in nutritional changes. Using isotopic techniques, the nitrogen fluxes through *Acartia tonsa* (Copepoda: Calanoidea) from the OMZ off northern Chile (23°S) were traced.

Starved females were fed with ^{15}N-labelled *Thalassiosira weissflogii* and incubated under hypoxia (1.2mg/L) and normoxia (9.0mg/L) at 15°C during 12-24 hours. The incorporation and transference of nitrogen towards fecal pellet and eggs were evaluated.

Our results show a net nitrogen incorporation rate by *A. tonsa*, 58% higher under hypoxia (0,020±0,012 µg N $ind^{-1}h^{-1}$) than in normoxia (0,013±0,003 µg N $ind^{-1}h^{-1}$). Additionally, the rate of nitrogen transference toward the eggs under hypoxia was 5 times the rate under normoxia. Along with this, under hypoxia there was 8% reduction of the C/N ratio. Nitrogen transference to the fecal pellets was three times higher under hypoxia than in normoxia and a 35% reduction of the C/N ratio was observed. Our results show that reduced oxygen would have nutritional implications not only to *A. tonsa*, but also towards higher levels which fed by these copepods. Changes on the pelagic structure community due to the climate change can be evaluated, predicting potential changes on the biogeochemical fluxes in the OMZ of the EB.

S8 Posters
Climate change impacts on marine biodiversity and resilience

S8-P1

Identification of coral reef bleaching warming in Gulf of Kachchh using climatology parameter by geospatial techniques

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Coral reefs are playing vital role in ecosystems, providing a source of earnings, food and coastal protection for many human beings. The coral reefs are massive biological set up in the coastal seas and have taken several millenniums to attain current form. Coral bleaching has been one of the significant contributors to the increased deterioration of reef health. The research paper focuses on bleaching of coral reef along the Gulf of Kachchh. The study area extends from 69˚ 37' 00'' E to 69˚ 45' 00'' E and 22˚ 24' 00'' N to 22˚ 30' 00'' N along the southern shore of the Gulf of Kachchh in the Jamnagar District of Gujarat state, India. In this study coral bleaching warning based on the thermal stress. Their density and health may vary as per growing conditions like salinity, temperature, wave actions *etc*. Some of the common species are *Favites, Porites, Montipora, Favia, Symphylliaand turbinaria, Cyphastrea, Platygyra*. Coral reefs are especially susceptible to predicted global change because they bleach quickly and dramatically in response to increased Sea Surface Temperatures (SSTs). The parameters SST climatology, bleaching HotSpot and degree of heating week were used for this research study. These parameters generated using SST data retrieved from Advanced Very High Resolution Radiometer sensor on-board national oceanic and atmospheric administration. The nocturnal sea surface temperature is an important parameter to assess the thermal conditions and intensity of the bleaching.

S8-P2

Vulnerability of tropical and temperate coastal organisms to climate change

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The threat of global climate change has fostered the current interest in understanding species' thermal limits. Rocky shores are predicted to be one of the habitats hardest hit by temperature rise, making its inhabiting communities excellent experimental material for climate warming studies. The aim of the present work was to (1) estimate the upper thermal limits (CTMax), (2) the intraspecific variability in upper thermal limits, and (3) the warming tolerance (Maximum Habitat Temperature - CTMax) of coastal organisms. Differences in biological groups (decapod crustacean *vs* fish) and the effect of region (tropical *vs* temperate) and habitat (intertidal *vs* subtidal) were investigated. Specimens were collected and tested during the summer of 2014, in Southeastern Brazil and Western Portugal. No differences were found when comparing decapod crustaceans and fish. CTMax was higher for tropical (34.2^{o}C to 39.7^{o}C) than temperate species (27.4^{o}C to 38^{o}C) and also higher for intertidal than subtidal species. Intraspecific variability was higher in temperate species than in tropical species, but no difference was found between intertidal and subtidal species. Warming tolerance was higher for temperate species than for tropical species and higher for subtidal species than for intertidal species. This study confirms previous reports that stated that the species with the highest thermal limits have the lowest warming tolerance. Our results strongly suggest that tropical intertidal species are the ones in greatest jeopardy considering climate warming trends. This study contributes to the ongoing scientific debate on which organisms face a higher risk from climate warming: tropical or temperate.

S8-P3

Network structure of estuarine food webs – The role of humans and climate change

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The Tagus estuary food web was compiled and three datasets were produced representing its past (1970's), present (2000's) and future food web (2100's). The Tagus food webs were compared to 8 other estuarine and 15 non-estuarine food webs. The Tagus estuary food webs presented properties in the same range as other estuarine and non-estuarine food webs, suggesting that food webs from estuarine, marine, stream, lake, and terrestrial ecosystems share fundamental organizational characteristics. High omnivory was found for estuarine and marine food webs, due to uneven resolution of the food webs and/or prevalence of opportunistic feeding. Niche model was poorly fit to the Tagus estuary food webs, as well as to the other estuarine food webs analyzed. The overall fit of the probabilistic niche model (PNM) to the Tagus food webs was significantly better than that of the niche model. Generalists' diets displayed a core niche structure, with most resources grouped along a limited interval of the niche dimension. The addition of 16% new nodes as a result of climate change did not impact overall structure in terms of niche model fit and PNM fit. Because more species will be added than lost, there will be an increase in species richness. The role of humans, as the top predators with the most prey links, will be reinforced in the future since many of the new species are commercial species. A highly omnivorous shark is predicted to enter this system, with potential to impact the abundance of species already under fishing pressure.

S8-P4

A novel method to identify the effects of climate change: Potential insights for future biodiversity and ecosystem resilience

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Forecasting the threat of climate change to the biodiversity and resilience of marine ecosystems requires understanding how each component species may respond to modified conditions. For some species, assessments can be achieved using established tests which are often ecotoxicological in nature. Increasingly, however, it is recognised that contemporary methods overlook many species. Further, the species considered are not necessarily those of greatest interest due to their role in ecosystem structure and function, but rather those amenable to testing; *i.e.* available for collection and/or suitable for laboratory testing. Given the desire to understand potential effects of global-scale change on a wider variety of species than is currently possible, it was our goal to develop a novel approach for quantifying the effect of abiotic change that could easily be applied to a range of organisms. Here, we outline a new method that could be used to consider potential impact(s) of climate change on a range of marine organisms by focussing on the key life cycle event of reproduction, specifically by quantifying the swimming behaviour of sperm. Key advantages of this method are that it is relatively inexpensive, rapid and of potentially broad utility. Such features mean this method would facilitate consideration of predicted conditions on a broad range of species over previously unassessed spatial and temporal scales. We propose this method could provide an additional response variable to identify the effect of climate change on a range of species, potentially contributing important insights to forecasts of future biodiversity and resilience.

S8-P5

Marine climate change impacts and adaptation report card for Australia

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The Marine Climate Change Report Cards for Australia (2009 and 2012) provide information about the observed and projected impacts of climate change on marine ecosystems and taxonomic groups and present potential or implemented adaptation actions. Knowledge of observed and projected changes in ocean physics and chemistry as well as climate variability was also synthesized. Over 80 authors from 35 universities and institutions contributed to the syntheses. Key findings of the 2012 Report Card include warming temperatures are influencing the distribution of marine plants and animals, with species currently found in tropical and temperate waters moving polewards; winds over the Southern Ocean and ocean current dynamics strongly influence foraging for seabirds that breed in southeast Australia and feed close to the Antarctic each summer; some tropical fish species have a greater ability to acclimatize to rising water temperatures than previously thought; the impacts of two years of extreme events, including floods and heatwaves, are widely evident in the marine environment; the Australian Science community is widely engaged in research, monitoring and observing programs to increase our understanding of climate change impacts and inform management; adaptation planning is underway, from seasonal forecasting for fisheries and aquaculture, to climate-proofing of breeding sites for turtles and seabirds. Plans for the third version of the Marine Report Card include inclusion of indicators to monitor adaptation progress.

S8-P6

Histological and scanning electron microscopic studies on internal parasite *Echinorhynchus* sp in yellowfin tuna (*Thunnus albacares*)

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Adult parasitic worm *Echinorhynchus* sp. was collected from the small intestine of *Thannus albacares* from Nagappattinam south east cost of India. The study fish was frequently and naturally infected by acanthocephalan parasite. Light microscope as well as scanning electron microscopic studies revealed that the adult worm possessed a proboscis which was long, cylindrical with a uniform width measuring 0.44±0.02 mm in length and 0.12±0.02 mm in width. Proboscis hooks observed by scanning electron microscopy where large, uniform in size (14-16 rows of 26 hooks each) with a row of longer hooks at the base comparison. Histopathology of the tissues showed totally destroyed ultrastructure of the infected intestinal tissues. Such as mucosal epithelium, stratum granulosum, lamina propria, muscular and serosa of the wall of the intestine forming a tunnel surrounded with collagenous fibers and granulocytes. Inflammation, granular tissue formation, connective tissue proliferations were found associated with the, infected tissues. Moreover, it may lead to complete degrades of the host intestinal tissue. The present study was carried out histopathological changes due to the *Thannus albacares* parasitization on the internal organ and description of *Echinorhynchus* sp resembled the parasite in the general morphology was recorded.

S8-P7

Effect of ocean acidification on white spot syndrome virus (WSSV) replication in juvenile European lobster (*Homarus gammarus*)

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Climate change mediated alterations in seawater chemistry reduces seawater pH and affects the saturation states of biologically important calcium carbonate minerals. Such changes can adversely affect shell formation of commercially important shellfish and such effects appear to be amplified in the presence of co-stressors, such as temperature or food availability. Reported changes in the growth, development and shell composition of the American or European lobster under future ocean acidification (OA) conditions is suggestive of adverse effects on bioenergetic or homesostatic processes. This study considered the effect of the highly pathogenic and economically important White Spot Syndrome Virus (WSSV) on juvenile European lobsters (*Homarus gammarus*) at two temperatures (12 or 20°C) and three pCO_2 regimes (390, 800 or 1300µtm). The growth, development and survival of disease challenged animals were monitored, alongside replication and expression of the virus in tissue by qPCR. These data were then compared to the same biometrics in unchallenged lobsters. Survival, moult frequency and growth were highly variable within and between treatments. Growth and development of animals at 12°C was slower than at 20°C. At 12°C, the viral loading of WSSV in exposed animals was very low under all pCO_2 conditions. At 20°C the viral loading was significantly higher in animals held at 800 or 1300µatm pCO_2 compared with all other treatments. The increased replication and spread of viral diseases like WSSV under future climate change scenarios could have significant economic and environmental impacts beyond the direct effects of OA on individual shell composition, growth or development of commercially important shellfish.

S8-P8

Coral reef resilience to climate change in the Gulf of Thailand and the Andaman Sea

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Major coral bleaching events have led to widespread coral mortality in recent decades. The assessment of coral reef resilience to climate change is an important task but has been difficult to carry out because of a lack of empirical scientific data. We quantitatively assessed coral reef resilience at 20 study sites in the Gulf of Thailand and the Andaman Sea about two years following the 2010 severe bleaching event based on the percentage of non-bleached coral colony, the percentage of surviving coral colony and the density of juvenile corals at the study sites. The coral reef resilience varied greatly among the study sites and major reef groups according to their community structure, largely due to the differing bleaching resistance and tolerance of the dominant coral species. The high resistant study sites were in the Inner and Eastern Gulf of Thailand while the lowest one in the North Andaman Sea. The percentages of surviving coral following the bleaching events in 2010, or the tolerance, varied significantly between the study sites. Most study sites in the Gulf of Thailand had much lower coral recruitment rates compared to other reef sites in Thai waters. The study site in the inner Gulf of Thailand had the highest resilience, while the study site in the Andaman Sea had the lowest. This study provides insights into the degree to which coral communities in the Gulf of Thailand and the Andaman Sea are resilient to climate change, mainly coral bleaching, based on empirical scientific evidence.

S8-P9

Current status of microbial activity at Pareviwella reef Tangalle southern Sri Lanka

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Coral reefs ecosystems are sensitive to global changes in climate and human activities. The relationship between microbial activity and chemical substances available in the water column due to sensitive process from climate to human activity is not very clear. This area of research is needed to understand the ecosystem processes for conservation initiatives. Therefore the study aims to identify the current status of shallow fringing reef Paraviwella (FRP) at Tanagalle South Sri Lanka (6°01′17.07″N, 80°48′01.21″E) from 12th of February 2014 to 31st of September 2014, with reference to microbial activity and quality of water in reef water column. Benthic assessment shows that the FRP is dominated by living corals (57.6 ± 11.8%) and algae (22.3 ± 12.2%). Chemical conditions of sea water were measured, following parameters were used to assess *viz*. Dissolved oxygen (DO), Temperature (T), Salinity (S), Depth (D) and Turbidity (Tb). Bacterial abundance was measured using direct counting method (Epifluorescent microcopy). Also culture experiments to show the microbes selective agar plates (Thiosulfate Citrate Bile salts Sucrose (TCBS agar) agar for *Vibrio* and, Xylose Lysine Desoxycholate (XLD agar) agar for *Salmonella*). Results disclosed that water quality (DO=8.60 ± 1.12 ppm, T=29.3 ± 0.3°C, S=34 ± 1ppt, D=54.1 ± 17 cm, Tb=3.1 ± 0.6 NTU) and microbial abundance (MA) (mean Total MA= 4.5×10^6 ml^{-1}, mean *Vibrio* abundance = 65.75 CFU/ml^{-1} and mean *Salmonella* abundance = 1 CFU/ml^{-1}) at FRP were within the range of suitable condition for growth of corals and other associated organisms. Continuous monitoring is essential to describe the situations with relation to changes of climate of human activities.

S8-P10

Marine assemblages on natural shores and coastal defence structures

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Urbanization is a global trend. The amount of natural habitat converted for urban use is increasing globally. Natural habitat destruction and its replacement by artificial structures will continue in the future due to rising and stormier seas predicted from global warming. There is a growing interest in understanding the role of these artificial habitats in coastal ecosystems, essential information to predict the influence of habitat change on the distribution, abundance, dynamics and structure of intertidal communities. Artificial habitats provide different environment for many intertidal species, usually supporting epibiotic assemblages that differ from those on natural reefs. This work focuses on the extent assessment of differences among natural basaltic shores and artificial substrates made of concrete and basalt, materials usually used in building urban structures on volcanic islands. The characterization of the relative abundances and scales of spatial variability of intertidal macrobenthic communities revealed that species richness did not vary significantly among habitats, although assemblage composition and the relative abundance of key organisms differed between natural and artificial shores. Particularly, densities of gastropods inhabiting mid and high intertidal levels were significatively reduced in artificial habitats, providing useful information for the successful implementation of eco-friendly coastal defence structures. The ability to relate mitigation efforts to local benefits can provide, *e.g.*, stock enhancement of exploited species or biodiversity conservation advantages. Manipulative experiments testing for the effect of natural vs artificial substrates at several temporal/spatial scales are in progress to determine the processes responsible for shaping the intertidal assemblage structures in artificial habitats.

S8-P11

Effects of climate change scenarios on a coral reef meiofauna community

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Decrease in ocean pH and elevation in temperature are predicted due to rise in atmospheric CO_2 concentrations. A microcosm experiment was conducted to investigate the effects different climate change scenarios on a phytal meiofauna community from a coral reef. Community samples collected from the coral reef subtidal zone (Reef formations of Serrambi Beach, Pernambuco, Brazil), using artificial substrate units, were exposed to a control (ambient seawater) and to three climate change scenarios (for each scenario one level of pH decrease and temperature increase in seawater was established). The choice of these scenarios follow predictions for the year 2010 and 2250 based in different emissions scenarios of greenhouse gases (IPCC 2013, 2007; Caldeira and Wickett 2003, 2005). After 30 days of exposure, major changes in the structure of meiofauna community were observed among the different scenarios. Permanova a posteriori comparisons showed no differences between control and scenario I ($t=1.34$; $p=0.08$). However, differences between control and scenario II ($t=2.2$; $p=0.003$), control and scenario III ($t=3.6$; $p=0.003$) and also among all three scenarios ($p<0.05$) were observed. Meiofauna total density and the density of its dominant groups were negatively affected by climate change scenarios. Copepoda Harpacticoida and their nauplii showed great sensibility even at the scenario I. The results presented here show that impacts of ocean acidification are even more damaging and faster if followed by significant increases of seawater temperature.

S8-P12

Response of *Halimeda* sp. to a climate change scenario

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Over the past centuries human activities such as emissions of greenhouse gases have become an additional component affecting the climate system. According to IPCC, atmospheric concentrations of these gases will continue to rise. Thus, an average increase in global temperature of 1.4 to 5.8°C by the end of the 21st century is expected. The increase of greenhouse gases concentrations may also cause a decrease in pH of ocean surface waters up to 0.4 units in 2100. Coral reefs are formed mostly by sensitive calcifying animals. Species of the genus *Halimeda* were shown to be very susceptible to ocean acidification. The aim of this study was to evaluate the impact of a climate change scenario on *Halimeda* sp. during four weeks using a microcosm experiment. Forty *Halimeda* sp. individuals were collected from the coral reef formations of Serrambi Beach, PE, Brazil. At the laboratory, twenty individuals were maintained in control (field seawater conditions) and the other twenty individuals were exposed to a scenario of climate change (increasing seawater temperature by 2.5°C and decreasing pH by 0.3 units). Weekly, five replicates of each treatment were sampled and measurements of the amount of chlorophyll *a* and β were assessed. The chlorophyll extraction was performed following the methodology described by Dos Santos *et al*. (2004). Results indicated significant differences in the proportion of chlorophyll *a*, with a decrease in samples exposed to the scenario of climate change when compared to control samples, probably due to environmental stress.

S8-P13

Enlargement and reductions on habitat of sub-tropical and boreal intertidal species of gastropods along Atlantic coast of Iberian Peninsula in a global warming scenario

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In the current global warming scenario several studies found similar range shifts of intertidal organisms. These range expansions or contractions of boreal and sub-tropical intertidal gastropods were firstly recorded by Fischer-Piette in the 1940s and 1950s along the north coast of the Iberian Peninsula. The Atlantic coast of the Iberian Peninsula due to its particular oceanographic conditions is the north and south range boundary of many intertidal sub-tropical and boreal species, respectively. These boundaries are constantly changing to fit with the shifting climatic conditions. In this study we explored changes on the distribution range of boreal and sub-tropical species of intertidal gastropods. They play a key role in shaping the structure of rocky intertidal assemblages and thus, changes in their diversity or abundance can have dramatic effects in rocky shore assemblages. Our results showed a significant range expansion of sub-tropical species (i.e. *Siphonaria pectinata*, *Phorcus sauciatus* and *Stramonita haemostoma*) while boreal species showed a range contraction (e.g. *Littorina saxatilis* and *Nucella lapillus*) and in some cases their presence was limited to some environments which seem to serve as refuge (e.g. *Littorina littorea*). Future research will explore the role of biotic and abiotic factors in these range shifts, ecological consequences in the rocky shore assemblages and changes in intra-specific diversity of boreal and sub-tropical gastropod species related to range shifts.

S8-P14

Coral bleaching in Brazil

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Coral bleaching has become a major threat to coral reefs worldwide. Bleaching occurs when an environmental stress causes a disruption in the symbiotic relationship between corals and their endosymbiotic algae zooxanthellae. Many sources of stress may cause coral bleaching, but mass coral bleaching has only been observed when anomalous ocean temperatures exceed the coral physiological tolerance. And this has been mostly observed during major *El-Niño* events, as for example, the ones of 1982/83, 1997/98, 2002/03, 2005, and, more recently, the strong and widespread event of 2010 when coral reefs from several areas in the world were exposed to a higher magnitude thermal stress. Reports of coral bleaching in Brazil date back to the southern hemisphere summer of 1993/94, and since then has been observed along its whole tropical coast, in oceanic islands and in coral "oasis" in subtropical zones as well. During 1997 summer, at the NE coast bleaching occurred when ocean temperature reached values between 29°C and 30°C, but corals recovered its normal colors when these temperatures returned to values between 26°C and 28°C. The strong *El Niño* event that began at the end of 1997, in the Pacific Ocean, caused a rise in sea surface temperature in Brazil, and a new bleaching event occurred, which was coincident with ocean thermal anomalies. From 2000 to 2010, severe coral bleaching events occurred during 2003, 2005 and 2010, all of which were coincident with temperatures anomalies of up 1°C. Considering all reports of coral bleaching in Brazil, the phenomenon appears to be strongly related to events of thermal stress. Although in most cases bleaching had affected several reef areas with a high intensity, until the 2010 event, no episodes of coral mass mortality were recorded.

S8-P15

Ontogenic development of tropical photosynthetic mollusks in a changing ocean

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Early life stages are expected to be more vulnerable to future environmental stress such as ocean warming and acidification. Here we investigated, for the first time, the combined effects of warming and CO_2-driven acidification on fertilization, development and juvenile survival of two tropical Opisthobranchs, *Berghia stephanieae* and *Elysia clarki*. It is worthnoting that these marine tropical sea slugs are commonly used as biological tools for scientific research particularly to study their chemical ecology and photosymbiotic associations.

Four experimental treatments (with temperatures of 26ºC and 30ºC; pH levels of 8.0 and 7.5) were tested with a factorial design. Contrary to warming, ocean acidification reduced the number of egg masses per individual and development in both species. Regarding *B. stephanieae*, the combined effects of warming and acidification were so outstanding that no egg masses evolved after the 6 day of deposition. Also, severe veliger deformities (body, shell and oral apparatus) were observed for both species under warming and hypercapnia (93 and 60% deformed veligers in *Berghia* and *Elysia*, respectively). Concomitantly, juvenile's survival was negatively impacted. Our study shows that these climate change-related variables may constitute the bottleneck for species persistence and ecological success of such photosymbiotic associations in the tropical oceans of tomorrow.

Cancelled

Microbial community structure in the Benham Rise, Philippines, Western Pacific Ocean

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Marine microorganisms are major players in biogeochemical cycles. However, their existence and diversity in the tropics is threatened due to changing ocean regimes, such as increasing sea surface temperatures in the Philippines (Peňaflor *et al.*, 2009) and potential shifts in large scale circulation due to the shifting North Equatorial Current (NEC) bifurcation latitude (Kim *et al.*, 2004). Despite the diversity and importance of bacteria, the microbial ocean is still greatly undersampled, particularly in tropical seas. This study sought to provide baseline data for microbial assemblages in the waters of the Northeastern Philippines, Western Pacific Ocean using next-generation sequencing of community DNA. Approximately 25,000 reads of the 16S rDNA V4 hypervariable region were generated for each of the samples taken from surface water (~10m), deep-chlorophyll maximum layer (~140-210m), upper mesopelagic zone (~300m) and the deep sea (~1000m). We observed niche segregation of prokaryotic microbes, as well as ubiquitous bacteria at different depths that correlated with the physicochemical properties of the water column. Here we provide a snapshot of microbial community across depth in an area of the Western Pacific Ocean that will potentially be affected by increasing sea surface temperature and probable shifts in large scale circulation. To our knowledge this constitutes the first report of marine microbial diversity in the Pacific seaboard of the Philippines.

S8-P16

Population density of *Bursatella leachii* (Mollusca: Gastropoda) in three estuaries of Ceará State, Northeast Brazil

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Bursatella leachii is an aplysiid mollusk that inhabits marine areas from the intertidal zone to depths of seven meters of warm temperate and tropical waters. The studies of biological activities of the cell tissues and ink produced by *B. leachii* have been a major interest of many researchers, where antimicrobial, antitumor and anti-HIV substances have been discovered. Few studies of population biology of this species have been conducted, and consequently, there is lack of information on ecology and intraspecific behavior. It is known that this animal often appears in large groups during the reproductive period when thousands of individuals can be observed in estuarine areas. The aim of this study was to estimate the population density of *B. leachii* in estuaries of three rivers from Ceará State, Northeast Brazil. In 2007, 2008 and 2009, monthly sampling using 50 cm^2 squares in 3 transects marked in each study area were conducted. The month that presented the highest density of *B. leachii* was October 2007 (3,2/50 cm^2 in Tabuba River; 4,8/50 cm^2 in Ceará River and 5,6 animals/50 cm^2 in Pacoti River). In 2009, individuals were observed only in Ceará River (September, 2 individuals) and, in 2010, no animal was observed. The sea temperature data for the years 2007 to 09 suggests that the rising seawater temperature could be affecting the presence of *B. leachii* in the shallow waters of estuarine areas of Ceará State.

S8-P17

Aplysia dactylomela (Mollusca: Gastropoda) from Rocas Atoll (RN – Brazil): Where did it go?

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Rocas Atoll, the only atoll of the Equatorial South Atlantic, is located at the top of a chain of submarine mountains in the South Atlantic Ocean, whose base is located at a depth of 4,000 m in the ocean bed, at 3°51'S Latitude and 33°49'W Longitude, 266 km from the city of Natal and 150 km west of the Fernando de Noronha archipelago, in the Brazilian Northeast. Since the end of the 20th century, with the effective implementation of research activities at REBIO (Biological Reserve), the Atoll has been studied more frequently, with several scientific studies focusing on geology, corals, foraminifers, and calcareous algae. The aim of this study is to determine *A. dactylomela* sazonality at Rocas Atoll and its reproductive period. Observations since 1991 determined that *A. dactylomela* always appears at Rocas atoll between October and December, when it is possible to observed several individuals in mating and spawning processes. From 2010 till now, this population decreased to critical levels, when no individual was observed. The sea temperature and currents data suggest that the rising seawater temperature and current changes could be affecting the presence of *A. dactylomela* at Rocas Atoll.

S8-P18

Impact of climate change on marine biodiversity in west coast of India

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This article reviews current and expected changes in marine biodiversity habitats in response to climate change in west coast of India. It then reviews how these changes may impact the marine biota of microbes, zooplankton, phytoplankton, dissolved oxygen, chlorophyll, fish diversity, total nitrogen, total phosphorous, and salinity. Increased water and atmosphere temperature was observed from 1997 – 2003 and significant trend was observed from time series data of above parameters in west coast of India. Nutrient composition of coastal waters showed variation in narrow range, for total nitrogen and total phosphorous respectively with exception in year 1997 and 2003. We conducted research on impact of climate change on marine biodiversity and result in altered community structure and diversity. We observed that marine ecosystems in west coast of India, rising atmospheric CO_2 and climate change are associated with concurrent shifts in temperature, nutrient input and oxygen content. Ecological resilience to climate change is a combination of resistance to increasingly frequent and severe disturbances, capacity for recovery and self-organization, and ability to adapt to new conditions. We discuss empirical evidence for how these ecological mechanisms contribute to the resilience of coastal marine ecosystems following climate change–related disturbances, and how resource managers can apply this information to sustain these systems and the ecosystem services they provide. Time series analysis of environmental quality parameters provides information on changes occurred in a region which provides us in determining the status of the region, impact of climate change and next course of action to be taken for abatement.

S8-P19

Effects of increasing seawater temperature on phytal meiofauna community

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The present study evaluated the effect of increased seawater temperature on the community structure of phytal meiofauna using an open experimental mesocosm system. Samples of two algae (*Halimeda* sp. and *Tricleocarpa* spp.) were taken from the coral reef on Arraial d'Ajuda Beach (Bahia, Brazil). Individuals of *Halimeda* sp. and *Tricleocarpa* spp. were randomly allocated to one of the four treatments consisting of four temperature levels (control and the increased temperature levels of 1.0, 2.0 and 4.5ºC above ambient) with four replicates each. After four weeks exposure, multivariate analyses for meiofauna showed differences among treatments for *Halimeda* sp. ($F=2.386$, $p=0.01$), but not for *Tricleocarpa* spp. Pairwise tests for *Halimeda* sp. showed differences between control and +1ºC ($t=1.77$, $p=0.028$) and between +1ºC and +4.5ºC ($t=1.42$, $p=0.028$). Anova results indicated that the major meiofaunal groups showed divergent responses to the impact of increasing temperature. In general, animal density increased at treatment +4.5ºC. In *Halimeda* sp., Oligochaeta density was higher at the treatment +4.5ºC compared to all others ($p<0.017$ for all), Ostracoda was higher at +1ºC compared to all others ($p<0.029$ for all) and Polychaeta was higher at +1ºC compared to control and +4.5ºC ($p<0.024$ for both). For *Tricleocarpa* spp., Oligochaeta density was higher in the treatment +4.5ºC compared to all others ($p<0.001$ for all), Chironomidae larvae density was lower in treatment +4.5ºC compared to +1ºC and +2ºC ($p<0.01$ for both) and Gastropoda was higher in +4.5ºC compared to +1ºC and +2ºC ($p<0.019$ for both).

S8-P20

Combined effects of climate change and methylmercury exposure on marine fish ecophysiology

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Climate change predictions indicate that oceans will become up to 4ºC warmer and ocean pH will drop 0.4-05 units. These changes are expected to drive deleterious impacts on marine organism's distribution and abundance. Moreover, ocean warming and acidification are both known to exacerbate the toxicity of pollutants (*e.g.* mercury) to many life history stages. There are considerable evidences that mercury levels (Hg) in the environment have greatly increased in the past century. Although most Hg in the environment is inorganic, some is converted to the highly toxic methyl mercury (MeHg), which bioaccumulates in fish. Elevated MeHg concentrations is known to increase neurodevelopmental abnormalities which may trigger deleterious effects on fish behavior, performance and health. The combined impacts of ocean warming, acidification and mercury pollution on marine species are not known. In this study, we investigated, for the first time, a set of biological responses to the combined effect of methylmercury exposure, warming (+4ºC) and acidification (ΔpH = 0.5 units) in meagre (*Argyrosomus regius*) juveniles, namely morphological, physiological and biochemical changes during 30 days. The potential cascading effects on the marine food webs are also discussed.

S8-P21

Estuarine neustonic communities: Oceanographic tool to relate climate change with fluctuation in salinity at southern Chilean fjords

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The Chilean austral zone (41°-55° S) is characterized by important variations of salinity due to the presence of rivers, snow, glaciar and rainy conditions. Neustonic communities in this area remain unknown and this research was proposed to describe the biodiversity, community structure and other roles played by the neuston between Guafo and Beagle Channel and the influence of diverse degree of estuarine condition (three sampling campaign, 2010-2014, 90 stations). This layer is important: it represents the boundary region of the air/water interface, covering ca. 71% of the planet's surface, being the largest ecosystem in the world; it is under the influence of diverse environmental and oceanographic factors, and shows direct response to the effects produced by climate warming/oceanographic change at subantarctic latitudes. In addition, mesozooneuston is crucial to feeding and survival of early stages of economically important fishes/shellfisheries and as source of organic matter.

We have observed significant changes in abundance, biomass and species richness of these neustonic communities in relation to salinity, detecting a latitudinal pattern. These ecological parameters showed higher magnitudes in salty than in dilute waters. Under an scenario of increased snow melting and rainy conditions associated to a warming climate in southern Chilean coast, such relationship could change. Therefore, continuous monitoring of subantarctic neustonic communities is highly recommended.

Other relevant information collected by us includes: monitoring of kelp macrofauna biodiversity, presence of exotic ascidians, influence of rivers discharge on the subtidal macrobenthos and reproductive phenology in gastropods of the Magellan waters, Chile.

S8-P22

Distribution patterns of native and exotic ascidians in two areas of Chile with contrasting oceanographic features and human activity record

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The biodiversity of ascidians in the Magellan Strait (53º Latitude) and Coquimbo (29º latitude), Chilean coast, was recorded in its zones which are markedly different, with influence of the Humboldt current in the north, and a mixture of Atlantic and Pacific waters with freshwater influxes in the Magellan zone (sampling during 2013 by SCUBA diving and surveys of artificial structures. A total of 28 species were identified, which represents a low diversity compared with temperate-tropical areas, but it is nevertheless significant for such a restricted survey (*e.g.* Sanamyan and Schories report only 9 species for the Magallanes Strait in 2003).

No species occurred in both regions, highlighting the very different environmental conditions of subantarctic vs temperate-cold waters. Observation on in aquaculture facilities and artificial structures in harbours and piers, no exotic species was found in the Magellan region; inversely, 6 out of 15 (40%) species found in northern Chile were introduced species. Coquimbo has a history of ship traffic dating back at least 150 years, and aquaculture of native scallop and a exotic abalone have been deployed for ca. 35 years.

Magellan Strait have a history of ship traffic dating back nearly 500 years and over 25 years of sustained mussel and salmon aquaculture activity. However, is apparently free from introduced species. Cold and estuarine waters could be the determinant factor hindering the development of exotic ascidians. The ongoing warming in the Southern Cone may change this picture and continued monitoring is strongly advised. The authors acknowledge funding by CONICYT and Universidad de Magallanes, Chile.

S8-P23

Coral bleaching in a highly turbid environment: A reef monitoring through 2 years in an equatorial coast (NE, Brazil)

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The degradation of reef ecosystems has increased rapidly in global terms because local anthropogenic impacts and effects of climate change, such as bleaching. Most research has been conducted in the Caribbean and Indo-Pacific, especially in coral reefs. Bleaching is already observed in semiarid regions such as the South Atlantic coast (NE, Brazil) who owns more resistant to changes in sea surface temperature (SST) and turbidity and lack of true coral reef species. Underwater images were collected using SCUBA equipment in the reef environment on Pecém region (state of Ceará) in order to analyze the structure of a monotypic assembly formed by the coral *Siderastrea stellata* and indicators of bleaching. The data collection period was between 2013 and 2014. The biological data were compared to data from SST and turbidity obtained through remote sensing. Bleaching rates ranged from 30 to 80% of the colonies. The SST ranged from 26.5 to 29 ° C without the presence of anomalies. The data showed a higher incidence of bleached corals between the months of May and June (60-80%) that are associated with higher values of SST, low-level winds and turbidity. The reduction in turbidity allowed possibly higher incidence of ultraviolet rays, intensifying the bleaching process. These facts have not yet been documented for coastal reefs of semiarid coast of Brazil and need a longer term monitoring, in order to understand the role of natural and anthropogenic forcing.

S8-P24

Predator-prey synergism – A novel perspective in ecology

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"From an antagonistic to a synergistic predator prey perspective: Bifurcations in marine ecosystems" is the title of a book that was published by Elsevier in 2014. The book presents predator-prey synergism as a novel perspective in ecology, defined as predator-prey relationships enhancing abundances of both predator and prey. The idea emerged during analyses of near-century long time series of observations of marine coastal ecosystems, but it is suggested that synergism may be important in some terrestrial systems too. Predator-prey synergism has wide-ranging implications for management of marine ecosystems and for theories in ecology and evolution. Resilience in marine ecosystems may be explained mechanistically by synergism, as may repeat incidents of bifurcations observed in the long time series. Bifurcations are sudden and persistent regime shifts as a result of gradually changing environmental conditions. It is suggested that global warming may induce bifurcations which in turn may result in recruitment failures in fishes and substantially reduced fish abundances.

S8-P25

Assessing impacts of ocean acidification on energy status of marine invertebrates

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In the marine environment, anthropogenic increases in atmospheric CO_2 are causing a reduction in pH and considerable attention is focussed on determining the impacts of ocean acidification (OA) at the individual, species and ecosystem level. Ongoing OA research at Bangor is investigating the physiological costs of coping with combined changes in pH/temperature, or pH/Salinity, in marine decapod crustaceans (*Carcinus maenas*, *Cancer pagurus*) and bivalve molluscs (*Mytilius edulis*) to determine whether animals will be able to adjust their physiology to cope with the changing environment and what the cost will be in trade-offs in energy expenditure. The 'cellular energy allocation' (CEA) technique was developed by aquatic toxicologists as a bioassay to provide a rapid means to assess energy status and overall condition through the assessment of energy consumption and energy reserves. The CEA technique is based on a biochemical assessment of the metabolic balance of the test organism: energy consumption (Ea) and energy reserves available for metabolism (Ec) are quantified biochemically using standard laboratory assays [Electron Transport System activity (Ea) vs. lipid, sugar and protein content (Ec)] and integrated as an indicator of the metabolic condition (Ea/Ec). Thus, a decline in CEA indicates either a reduction in available energy or a higher energy expenditure, both resulting in a lower amount of energy available for growth or reproduction and reflects the overall energetic status of the organism. The use of CEA in assessing the impacts of OA on energy status of marine invertebrates in multistressor experiments will be reviewed.

S8-P26

Metabolic responses of two species of brachyuran crustaceans to ocean acidification and reduced salinity

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Two species of brachyuran crustaceans with contrasting abilities to compensate for salinity change were exposed to an elevation in pCO_2 (IPCC forecasts for 2100) and to a salinity reduction known to challenge osmoregulatory capacities, in order to assess associated metabolic costs. The highly tolerant and invasive European shore crab, *Carcinus maenas*, and the less tolerant edible crab, *Cancer pagurus*, were exposed for 12 months in a 2-way crossed design to: pH 8.1 and 100% SW; pH 8.1 and 80% SW; pH 7.68 and 100% SW; pH 7.68 and 80% SW. Standard rates of whole-organism oxygen uptake were determined after 1, 3, 6 and 12 months exposure, and haemolymph acid-base status and osmolality measured in order to assess changes in metabolism and the ability of the crabs to compensate for alterations in seawater carbonate chemistry and ion concentrations. *C. maenas* was able to osmoregulate in 80% seawater and to maintain haemolymph acid-base status over the 12 month period. In contrast, *C. pagurus* struggled to maintain its haemolymph osmolality above that of the surrounding seawater but managed to maintain haemolymph acid-base status by elevating [HCO_3^-] levels in response to elevated pCO_2. Rates of oxygen uptake in both species varied among treatments and over time. Under the combined treatment of elevated pCO_2 and reduced salinity (pH 7.68 and 80% SW), survival was greatest in *C. maenas* but lowest in *C. pagurus*. Results will be discussed in the context of global climate change.

S9 Posters
Impact of climate change on ecosystem carrying capacity via food-web spatial relocations

S9-P1

Life strategies and dietary interactions of copepods in the northern Benguela upwelling system

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Ecophysiological adaptations, dietary preferences and trophic positions of calanoid copepods from the northern Benguela Current off Namibia were determined via lipid contents, lipid class compositions, marker fatty acids and stable isotope analyses, respectively. Three of the dominant calanoid copepod species deposited primarily wax esters, four accumulated triacylglycerols and another three species were characterised by high phospholipid levels, probably reflecting different life strategies. Biomarker approaches (via fatty acids and stable isotopes) revealed a wide spectrum and complex pattern of trophic positions for the various copepod species, but also highlighted the dietary importance of diatoms and dinoflagellates. The key species *Calanoides carinatus* and *Nannocalanus minor* occupied the lowest trophic level (predominantly herbivorous) corresponding to high amounts of fatty acid markers for diatoms (*e.g.* 16:1(n−7)) and dinoflagellates (*e.g.* 18:4(n−3)). These two copepod species represent the classical link between primary production and higher trophic levels. All other copepods were omnivorous or carnivorous, hence belonged to secondary or even tertiary (some deep-sea copepods) consumers. The calanoid copepod species cover the entire range of $\delta^{15}N$ ratios, as compared to $\delta^{15}N$ ratios of all non-calanoid taxa investigated, ranging from filter-feeding salps to adult predatory fish. These data emphasise that the trophic roles of calanoid copepods are far more complex than just interlinking primary producers with pelagic fish. These data need to be considered in the context of climate change and potential regime shifts for the development of realistic food-web models of coastal upwelling systems.

S9-P2

Impact of hypoxia on zooplankton communities in the subtropical and tropical Atlantic Ocean

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Extensive parts of tropical and subtropical oceans are characterized by oxygen minimum zones (OMZ) with hypoxic conditions at intermediate water depths. These OMZs are predicted to increase in spatial extent and intensity in the course of climate change. Increasing hypoxic conditions in the ocean will affect pelagic organisms such as zooplankton, restrict their distribution ranges and/or act as barrier for diel or ontogenetic vertical migrations. On the other hand, OMZs could provide a refuge for hypoxia-tolerant species from predation and/or competition by more sensitive species. In order to test whether OMZs of the Atlantic Ocean affect pelagic communities already in the current state, respiration rates, hypoxia tolerance and vertical distribution of zooplankton organisms, mainly copepods, have been determined in different regions of the Atlantic Ocean, including the Cape Verde archipelago, the Angola Basin and the northern Benguela upwelling system off Namibia. A novel experimental setup was developed for respiration measurements with small zooplankton specimens based on multi-channel optode respirometry. In addition, molecular genetic methods were applied to establish whether the OMZ represents a barrier for ontogenetic vertical migration and, hence, gene flow in the dominant copepod *Calanoides carinatus*. While hypoxia effects on respiration rate and vertical distribution were evident, the threshold concentrations of dissolved oxygen, at which these effects occurred, were generally lower than current *in situ* oxygen concentrations so that pelagic ecosystems in the Atlantic Ocean for the time being still seem to be less affected by hypoxia than their counterparts in the Pacific Ocean.

S9-P3

Integrating species distribution, phenology, body size, and abundance to evaluate climate impacts on marine trophic interactions

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Studies evaluating trophic interactions under changing climate conditions typically focus on independent effects of shifts in spatial or temporal distributions, but climate change is expected to affect marine organisms in a variety of ways, including through changes in their spatial distributions, seasonal phenology, body size, and population abundance. A more holistic evaluation of the food-web impacts of climate change requires considering the joint effects of these factors on predator-prey interactions.

This presentation will describe the conceptual rationale and present simple models for integrative analyses of multiple pathways through which how climate-related impacts can affect trophic interactions. Examples focused on Atlantic cod and American lobster in the Gulf of Maine (USA) will be used to demonstrate this integrative analytical approach. These examples will evaluate the independent and joint influence of shifting spatial and temporal distributions, body size, and population abundance on predator-prey relationships and interaction strength. Future plans to use these insights to develop predictive models of species interactions will be described.

S9-P4

Consequences of hypoxia on distributions, species composition, predator-prey interactions, and energy flow in a pelagic marine ecosystem

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Hypoxia is a significant and growing threat to coastal and estuarine ecosystems worldwide, yet our understanding of the impacts on pelagic food webs, and ultimately fisheries, is hampered by limited knowledge of how species-level responses translate to ecosystem changes. We are addressing the question "Does hypoxia affect energy flow from mesozooplankton to pelagic fish?" by examining direct and indirect mechanisms through which hypoxia may alter predator-prey interactions in Hood Canal, WA (USA), a region that experiences moderate seasonal hypoxia. We are testing hypotheses that 1) direct, physiological effects on zooplankton lead to indirect effects on trophic links through changes in zooplankton species composition and prey quality (*e.g.*, shifts from crustacean to gelatinous species, or calanoid to cyclopoid copepods), 2) differential changes in distributions affect predator-prey overlap, and 3) physiological effects on fish lead to reduced predation and hence, growth. Using bioacoustics, net sampling, stable isotopes and diet analyses, we examine the above hypotheses and generate data for a variety of models that link observed shifts to overall changes in food web energy flux. Our research to date shows support for some of the above hypotheses on distributional and species shifts, however compensatory responses by species and communities may negate these apparent effects, allowing maintained trophic coupling and sustain productivity of upper trophic level species.

S10 Posters
Forecasting climate change impacts on fish populations and fisheries

S10-P1

Decline in puerulus settlement in the western rock lobster fishery in Western Australia: A climate change effect?

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The western rock lobster fishery is one of the best fisheries in Australia to examine effects of climate changes because of its long time series of data to assess trends in the fishery. Its location in the lower west coast of Western Australia has been identified as one of the hotspots of long-term increases in water temperature in the Indian Ocean and is also affected by a long-term reduction in winter storms. These trends are projected to continue. The decline in puerulus (post-larval stage) settlement in the seven years (2006/07 to 2012/13) appears to be due to long-term environmental factors. Water temperature increases in winter have resulted in an earlier onset of spawning which may be creating a mismatch with other environmental factors affecting the larvae during its 9-11 month larval phase. There has been a pro-active management response before these puerulus year-classes entered the fishery (3-4 year lag between settlement and recruitment to the fishery) with a significant reduction in fishing effort (~70%) since 2008/09. The fishery has also moved to a catch quota system with maximum economic yield as its target which has provided increased resilience to the stock. The fishery provides an example of an appropriate management adaptation response to the decline in recruitment abundance. The fishery has demonstrated the ability of research, management and industry to react quickly to changing abundance and highlights the value of reliable pre-recruit abundance for early detection of changes in abundance and early management adaptation response before fishing took place on the poor year classes.

S10-P2

Marine shallow water seascapes under a changing climate: A seagrass perspective

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The world's oceans are becoming increasingly threatened as a result of a myriad of anthropogenic factors such as eutrophication, overfishing, destructive tourism, ocean acidification and rising sea surface temperatures. Understanding the influence of seascape configuration on fish assemblages is a critical step towards a more holistic management approach, though it is not enough without an evaluation of the problems faced from climate change, as this is continuously altering the state of the oceans.

In order to determine the effects of a changing climate on an ecosystem level it is essential to find an approach that appropriately studies the potential effects at the proper scale. The use of landscape ecology is an increasingly well-regarded method, termed "seascape ecology" when used within the marine environment. An important aspect of seascape ecology is understanding habitat connectivity through species migrations. The use of Remote Underwater Videos (RUV) provides an invaluable tool for viewing species, particularly highly mobile species such as fish, in their natural environment without disturbance. The current project evaluated 30 seascapes in Skagerrak, Sweden, using beach seine netting and RUV fishing methods over two seasons in 2013, in order to determine the fish assemblages within seagrass meadows. The collected data will later be combined with offshore fisheries data in order to understand habitat linkages of species in deep and shallow water habitats. Data will be included in a climate change model to evaluate how factors such as run-off and proximity to deep water may alter the fish community under a changing climate.

S10-P3

Long-term trends in growth of Kamchatka chum salmon (*Oncorhynchus keta*) in relationship to climate and salmon abundance, 1927-2012

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Inter-annual trends in body size and intra-annual changes in growth of Kamchatka chum salmon in 1927-2012 were studied. From the 1930s to 1980s, the body size of Kamchatka chum salmon tended to increase, while after 1990s it sharply decreased. Annual growth dynamics showed different patterns. The first-year growth, estimated from intersclerite distances, enhanced from 1930s to 1950s and reduced from 1960s to 2000s. Growth dynamics in the third and fourth years of life were opposite. Chum salmon body size and scale increments for the third and fourth years correlated negatively to salmon abundance suggesting density-dependent effect. However, strong relation between growth and abundance occurred only in 1960-1990s. In addition to salmon abundance, Kamchatka chum salmon growth correlated negatively to the indexes of the ocean surface temperature, the ground air temperature and the heat content of North Pacific Ocean assuming that an important factor affecting long-term growth changes was water temperature. Our results corroborate suggestions of the previous study on Anadyr chum salmon showing that chum salmon growth reduction after the early marine period is likely to be a mixture of increasing abundance of Pacific salmon combined with changing ocean conditions. The role of climate and density-dependent factors has changed over the last century with increasing importance of climate conditions during last decades.

S10-P4

Modelling ecological responses of Pacific saury (*Cololabis saira*) to future climate change and its uncertainty

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An ecosystem-based bioenergetics model was used to investigate the responses of Pacific saury (*Cololabis saira*) to global warming. The model was forced by the projected sea surface temperature (SST) generated by climate models that formed the bases for the Intergovernmental Panel on Climate Change fourth Assessment Report (IPCC-AR4). Twelve climate models, which reproduced the Pacific Decadal Oscillation well compared with observations, were selected and B1, A1B, and A2 emissions scenarios were used. In total, 33 ensemble simulations were conducted, of which 24 (73%) showed a decrease in wet weight of Pacific saury. The migration pattern was modified in 11 (33%) cases. In these cases, higher SST and size reduction under global warming prevented or delayed the southern migration of saury in winter. As a result, egg production was enhanced by the higher availability of prey plankton in the modified spawning region. A case study to separate the direct temperature effects was conducted, in which prey plankton density was assumed to be the same as the control run. The results suggest that an SST increase will directly reduce juvenile growth, whereas a prey plankton density decrease has an influence on the growth of adults and migration pattern, and hence egg production.

S10-P5

Buoyancy and vertical distribution of Pacific Mackerel eggs and larvae and its climate change implication for the temporal variability of recruitment

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Vertical distribution of fish eggs and larvae is a crucial component for determining advection and recruitment variability. Little has been reported about the vertical location of Pacific mackerel *Scomber japonicus* eggs and larvae in Korean waters. Therefore, we measured the specific gravity of eggs and larvae using artificially fertilized eggs, and then simulated its vertical distribution to understand the distribution patterns in the spawning area around Jeju Island, Korea. All eggs were spawned from by raising broodfish (May-June 2013 and 2014), and the specific gravity of eggs and larvae was measured by density-gradient column (Martin In. Co. LTD). The egg specific gravity during the early stage ranged from 1.203-1.0211. In general, the fertilized egg showed a gradual decline in specified gravity until full development of the main organs, with a sudden increase just before hatching. However, specific gravity of larvae tended to increases with diel pattern from 4 to 16 days after hatching. Due to the different salinity in spawning area, the vertical location of eggs and larvae should be different interannually, which determines the various levels of advection as well as recruitment success.

S10-P6

The Brazilian sardine (*Sardinella brasiliensis*) landings and its relationship with the marine variability in the Southeast Brazilian Bight (SBB)

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This work presents an analysis of the influence of the marine climatic variability on the monthly catching of the *Sardinella brasiliensis*, in the Southeast Brazilian Bight (SBB) between 1990 and 2014. Remote Sensing data was used to obtain time series of Sea Surface Temperature and Chlorophyll *a* anomalies. In order to evaluate the relationship between these variables the methods of wavelets, cross-wavelets and cross-correlation were applied. The results show that the SSTA positive values are related to a decrease in catching sardines, while negative values of SSTA that are associated with increased production. We note that in the study area the observed SSTA are predominantly positive from the year 2000 and may be influenced to reduce the amount of sardines landed. The maximum and minimum values of SSTA occurred mainly at the time of recruitment to the adult stock or the beginning of the spawning season of the Brazilian sardine. The cross-correlation between the production of sardines and the concentration of chlorophyll *a* showed two peaks, one at 7 and another 3.5 years. The peak years of the chlorophyll concentration to, for example, 2007, the production of sardine will be greater with a lag 1.5 to 2 years. Factors such as SST, wind, Ekman transport and concentration of chlorophyll *a* govern the abundance and distribution of the Brazilian sardine, as they determine the amount of food that will ensure successful reproduction and recruitment of this species. All aspects should be considered for obtaining a coherent and sustainable fishing policy.

S10-P7

Impact of rapid warming on the Gulf of Maine ecosystem

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From 2004 through 2013, the Gulf of Maine warmed at a rate of 0.23° yr^{-1}. This rate is faster than 99% of the global ocean over that period. Few large marine ecosystems have experienced such rapid warming, and this provides a natural opportunity to study how ecosystems respond to changes in temperature. The zooplankton communities sampled by the continuous plankton recorder showed very little change over most of this period; however, the community did respond to the peak temperatures in 2012 and 2013. Some of the strongest changes observed have been in the fish community. There have been increasing reports of mid-Atlantic species such as black sea bass and butterfish in the Gulf of Maine, and many of the species in the National Marine Fisheries Service's annual bottom trawl survey show significant correlations with temperature. The abundance of northern shrimp declined to the point where it can no longer support a fishery, and warming has likely contributed to the collapse of Gulf of Maine cod. Even if cooler conditions return, the impact of this warming will persist for several years as cohorts born during the last few years grow and mature. The impact of the rapid warming on the fishery resources in the Gulf of Maine underscores the need to incorporate environmental conditions into fisheries management.

S12 Poster
Linking climate change to marine management objectives

S12-P1

South African ocean monitoring: A new era

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South Africa's Department of Environmental Affairs: Oceans and Coasts (DEA: O&C) policies focus on efforts of conservation and protection while allowing healthy economic growth and sustainable development. Recently, South Africa's first Oceans Policy was approved, unlocking the potential economic contribution the oceans can make in the fight against poverty, job creation and economic development. However, DEA: O&C has to ensure that there is a balance between economic development and maintaining a healthy environment. To this end, DEA: O&C has spearheaded an ocean monitoring system with partner organisations, a first of its kind on the African continent. The system of instruments and real-time data buoys has two goals. Firstly, to contribute to the decades of long-term data collected and be used for the development of ecosystem service indictors. These are tools that can be used in environmental management decision-making that incorporate not only science, but the economic and social realm. Therefore giving decision-makers a useful tool with regard to issues of climate change. And eventually, the ocean monitoring system will become an early-warning system that would be able to protect our coastline against environmental hazards and assist in managing disasters such as oil spills. DEA: O&C is in the first phase of the implementation of the ocean monitoring network.

General Poster Session

GP-P1

Overview and experiences gathering during boat tour in ocean of Ghana

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Oceans are vital in the tourism gathering and its promoting cultural attraction to an average citizen. A visit was made to an ocean in Ghana to observe the different usefulness and different weather conditions. The observation is that at the different interval there is an different weather, fishing activities were going on and people do come for tourism attractions and speed boat were observed, smoking of fish during the period . This paper gives different ways information that was gathered, pictures were taken, and questions were asked from the people that come to visit the place.

GP-P2

Variability of total alkalinity and total inorganic carbon in the western tropical Atlantic Ocean

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Using all available cruises in the Western Tropical Atlantic (WTA: 20°S-20°N, 60°W-20°W), we present the sea surface distribution of Total Inorganic Carbon (C_T) and Total Alkalinity (TA). Lowest C_T and TA are observed between 0ºN-15ºN/60ºW-50ºW and are explained by the influence of the Amazon plume during boreal summer. In the boreal autumn, when the Amazon waters are transported eastward through the North Equatorial Counter Current (NECC), very low C_T and TA are observed between 2ºN-10ºN/50ºW-20ºW. In the southern area, 20ºS-10ºS/40ºW-60ºW, highest values of C_T and TA are observed and can be explained by the rich-CO_2 waters flowing from African coast to Brazilian coast through the South Equatorial Current (SEC). The sea surface alkalinity in this whole region of WTA is highly correlated to the sea surface salinity during the year. C_T is also strongly correlated with SSS in the whole area mainly because of the influence of the Amazon River. Further offshore (10ºN-20ºN/30ºW-20ºW) and (15ºS-20ºS/25ºW-20ºW), the C_T is also explained by temperature variations.

GP-P3

Recent accretion rates in coastal seasonal floodplain, as an evidence of Global Change in Veracruz, Mexico

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Sea-level rise, one of the important impacts of Global Ghange, may cause flooding, aquifer salinization and habitat loss in coastal zones. The Intergovernmental Panel on Climate Change (IPCC) has reported a global mean sea-level rise of 3.2 mm y^{-1}. However, this increase is not homogeneous around the world. In Mexico, the scarcity of instrumental records (such as tidal gauges) hinders proper planning of sea-level adaptation and mitigation strategies. In certain conditions, coastal sediments may acrete following sea-level rise, therefore^{210}Pb dated sedimentary records may be used to indirectly assess local sea-level rise during *circa* 100 yr. The purpose of this work was to evaluate recent accretion rates by ^{210}Pb dating of two sediment cores, collected in coastal seasonal

GP-Posters

floodplains in the surroundings of the Salada Lagoon, Veracruz State, in central area of Gulf of Mexico. In order to study sediment provenance, other analysis included magnetic susceptibility, C_{org}, N, $\delta^{13}C$, $\delta^{15}N$. The C/N ratio and stable isotopes ($\delta^{13}C$, $\delta^{15}N$) showed evidences of marine organic matter sources in the sediment. The mean acretion rates (2.5 ± 0.3 mm yr^{-1} and 2.7 ± 0.4 mm yr^{-1}) are slightly lower, but in general agreement with the global mean rate of sea-level rise reported by IPCC.

GP-P4

Biogeochemical feedback processes in the oxygen minimum zone of the Benguela upwelling system

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Massive loss of nitrogen in oxygen minimum zones (OMZs) through anaerobic ammonium oxidation (anammox) and heterotrophic denitrification has been documented. Several studies investigated the dominant processes in the loss of nitrogen in OMZs worldwide. However, less focus has been given to related cycles including the silica and phosphorus cycles. It is known that these cycles are linked to the nitrogen cycle through various feedback loops. Any perturbations and feedback processes from the nitrogen loss could easily affect these cycles. The phosphorus cycle in particular could be more vulnerable than the silica cycle in OMZs as most of its cycling and transformations take place within the upper water column. With the Biogeochemical model for Eastern Boundary Upwelling Systems (BioEBUS) and PISCES, nutrient cycles, degradation and remineralization of particulate organic matter (POM) in the Benguela OMZ are simulated. The model resolutions allow for regional configurations and for short and long term analyses. PISCES is coupled with a Kriest model for representing sinking speed and abundance of POM aggregates using a power law function. Silica dissolution in the model is set to a constant in the upper ocean and assumes a steady state with depth. Findings from this study will allow integration of revised processes into these cycles and help evaluate the models. With regions of low oxygen expanding in the tropical Atlantic, it is becoming increasingly important to study present changes to nutrient cycles to aid in understanding and predicting future ecosystem implications.

GP-P5

UV sensitivity of planktonic net community production in ocean surface waters

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The net plankton community metabolism of oceanic surface waters is particularly important as it more directly affects the partial pressure of CO_2 in surface waters and thus the air-sea fluxes of CO_2. Plankton communities in surface waters are exposed to high irradiance that includes significant ultraviolet blue (UVB, 280–315 nm) radiation. UVB radiation affects both photosynthetic and respiration rates, increase plankton mortality rates, and other metabolic and chemical processes. Here we test the sensitivity of net community production (NCP) to UVB of planktonic communities in surface waters across contrasting regions of the ocean. We observed here that UVB radiation affects net plankton community production at the ocean surface, imposing a shift in NCP by, on average, 50% relative to the values measured when excluding partly UVB. Our results show that under full solar radiation, the metabolic balance shows the prevalence of net heterotrophic community production. The demonstration of an important effect of UVB radiation on NCP in surface waters presented here is of particular relevance in relation to the increased UVB radiation derived from the erosion of the stratospheric ozone layer. Our results encourage design future research to further our understanding of UVB effects on the metabolic balance of plankton communities.

GP

Synergetic effect of climate change, anthropogenic eutrophication and invaders on plankton community of the Black Sea

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Since the mid-70s the catastrophic changes occurred in the plankton community of the Black Sea. As the main factors considered invasive species and increased anthropogenic eutrophication, however, in the analysis of the long-term data on plankton, meteorology and hydrology in the open coastal waters of Crimea, shown that the impact of these factors has increased due to climate change.

In 1950-1976 observed moderate seasonal fluctuations of temperature of air and water, high wind-wave intensity and frequency of storms (repeatability of storms by force ≥ 4-5 was 35-56% per year). Large epiplanktonic Copepods and cold water species, living below the thermocline, were basis of plankton. The period after 1976 is characterized by cold winters, increased water stratification (the upper mixed layer decreased by 15-20 m), the reduction of wind-wave activity, and the widening range of seasonal fluctuations of air temperature and SST. The intensity of precipitation is increased, which led to a freshening of the surface layer of coastal waters (average rainfall of 1960-1975 was 23.63, in 1978-2000 - 48.67 mm, the average salinity in August 1947-1976 was 18.08, after 1980 17.66 ‰) and, consequently, an amplification in anthropogenic impact. The plankton abundance reduced and many species are disappeared. Increased summer SST since 1988 provided the optimum conditions for warm-water invaders.

Thus, after 1976 the part of species (aboriginal, mostly large or dominant in abundance) disappeared and some (warm-water species with small biomass and predators) has acquired favorable habitat conditions, that sharply impact on the overall abundance and composition of plankton.

GP-P6

Calcification response of the coral *Montastraea cavernosa* (Linnaeus, 1767) to heterotrophy during a bleaching event

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Once the increasing temperature has been predicted to cause up to 60% coral mortality, the heterotrophy might play an important role on the physiology of bleached corals. Understanding how corals respond to this environmental stressor has been placed as the main question to be answered to date. This study provides an experimental analysis of how shade-adapted colonies respond to a global warming scenario. Using a factorial MANOVA design, colonies of *Montastraea cavernosa*, one of the major Abrolhos Reef Complex reef-building corals, were adapted to shade conditions (equivalent to irradiance at 10 m), and exposed for eight weeks to a fed regime and temperature at 30°C. Colonies were fed with *Artemia nauplii* twice a week, the calcification rate was determined using a buoyant weight technique and the (photo) physiology by using a Diving-PAM. The results suggest that there is no interaction (p=0.09) between the two factors (bleaching and feeding), at which, it can be said that these factors were additive. However, just bleaching factor demonstrated significantly effect under Fv/Fm (p=0.0005). These findings indicate that calcification rate is influenced by neither bleaching nor feeding. And under this context, heterotrophy does not seem to have a critical role in the calcification of the studied coral species.

GP-P7

Modes of sea level variability in the South Atlantic

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Sea Level varies on all time scales and this is due to a large range of forcing processes. However, little is known about how the sea level of the South Atlantic Ocean responds to these processes. Thus, in this project, we aim to assess what drives the sea level variation in this ocean. We used the AVISO combined altimetry dataset, published indices of atmospheric variability, atmospheric reanalysis datasets of surface pressure, sea surface temperature from HadISST and tide gauge data from the PSMSL data base. The altimetry and tide gauge data were analyzed separately, but with the same method. First we divided their time series into annual cycles and residuals. Then, from the residuals, we calculated the mean sea level rise, performed an EOF analysis, correlated with the atmospheric indices and corrected the atmospheric pressure and temperature effect. A sea level dipole was present in all EOF analyses of the tide gauge data and this led us to calculate a new atmospheric index, here called the South Atlantic Index (SAI), to correlate with the sea level variation. As a result, the SAI, together with the PSA modes and SOI, were always significantly correlated with the sea level eigenvectors, even after the inverse barometer and thermal effect correction. The residuals contributed the most to the variance of the sea level in the South Atlantic, both in altimetry and the tide gauge data. Yet, this variance was not explained by the pressure or temperature effect studied in this work.

GP-P8

Climate response and spatial-temporal model on the inter-annual change of winter temperature-salinity in the East China Sea

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Based on the dataset of temperature and salinity in surface and bottom layers across the 30°N transect in the East China Sea in February from 1975 to 2013 and long time series data of China Ocean Station nearby, the mechanism and spatial-temporal model for the inter-annual change of winter temperature-salinity at surface and bottom layers in south Yellow Sea was studied with the methods of Rotated Empirical Orthogonal Function (REOF), maximum entropy spectrum analysis and delay correlation analysis, then a relationship between inter-annual change of salinity of Ocean Station and PDO Index was studied. Result shows that inter-annual change of winter temperature model was the response of local air temperature, wind stress, the phase of the PDO and ENSO event, inter-annual change of salinity was also affected by signals from Pacific.

GP-P9

Implications to erosion in coastal protected areas

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Changes in atmospheric conditions may alter wave characteristics, since ocean waves are generated by energy transfer from wind to the ocean surface. The ocean wave climate is highly variable and the importance of its temporal changes and extremes waves patterns extends from coastal ecosystems and morphology to engineering structures. The Espírito Santo (ES) coast (southeastern Brazil) is 410 kilometers long, has great diverse natural environments and also has important coastal activity. However, long term wave storm analysis has not been done for the coast of ES. This study, for the first time, characterizes the storms that occurred in five distinct location in the coast of ES and provide a trend analysis of the storms during the period 1948–2008. Due to the lack of visual and instrumental data in the study area, wave data from a global numerical model based on the WavewatchIII (WW3) forced by NRA-1 winds is used. Results indicate a trend for an increase in the number of extremes wave events with an average rate of $O(0.6)$ storms/year. In the last three decades, these changes have been more pronounced on the sites located in the southern coast. Moreover, results indicated November as the month with the strongest storm intensification pattern. No significant trends were found for storm duration, storm mean significant wave height (H_s) and storm mean wave pick period (T_p). Variations of coastal erosion events, due to wave storms patterns modifications, are analyzed using a beach profile numerical model for a coastal protected area in ES.

GP-P10

Downward export of carbon by diel migrant zooplankton in the northern Benguela upwelling system with regard to the OMZ

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Migrant biomass and carbon flux of vertically migrating meso- and macrozooplankton was calculated for shelf (< 200 m bottom depth) and oceanic (> 200 m bottom depth) regions in the northern Benguela upwelling system. Active carbon flux is based on migrant biomass and respiration rates. Especially in upwelling regions, oxygen minimum zones (OMZ) are a common feature and thus the impact of low oxygen concentrations (*i.e.* hypoxia) on metabolic rates also should be considered. Copepods were sampled with a 0.25 m^2 multiple opening and closing net (Multinet midi), while a larger net (1 m^2 MOCNESS) was used for the collection of euphausiids and decapods. Copepods were dominant in the upper 50 m of shelf areas with a migrant biomass between 23 and 47 mg C m^{-2}, whereas euphausiids were more abundant at oceanic regions with up to 1437 mg C m^{-2}. Decapods were absent at the shelf but important in greater depth at oceanic stations (> 150 mg C m^{-2}). Mass-specific respiration rates of individuals from the OMZ were reduced by 46-64% as compared to metabolic rates of specimens from surface waters. The resulting active carbon flux out of the upper 100 m by vertically migrating species was estimated with 4.3 mg C m^{-2} d^{-1} for shelf regions and 11.2 mg C m^{-2} d^{-1} for oceanic areas, which is equivalent to 4% and 35% of sinking POC, respectively. These data emphasize the crucial role of the OMZ for future developments of realistic carbon budgets under climate change scenarios.

GP-P11

Climate-driven changes in disturbed marine ecosystem: The case of the Neva Estuary

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The changes in disturbed ecosystems are usually attributed solely to man-induced factors. Estuaries are often centers of numerous human activities but, as transition zone between fresh and brackish waters, seem are also very susceptible to climate change. The Neva estuary (Gulf of Finland, Baltic Sea) is heavily impacted by anthropogenic activities, including eutrophication, pollution, dredging and biological invasions. Analyze of long-term data sets indicated that the anthropogenic impacts were strongly modulated by variations of climate which were the main reason of the most significant ecosystem changes during last century. Especially dramatic changes were recorded in the benthic communities. The amplitude of biomass fluctuations of macrozoobenthos reached locally 1–2 orders of magnitude. The immediate causes of these changes were climate-driven variations in hydrographical conditions, governed by large-scale atmospheric phenomena, particularly the North Atlantic Oscillation. In the easternmost inner part of the estuary (Neva Bay) the key factor was the decadal variations in the river runoff. In the western outer areas (eastern Gulf of Finland) the most important effect of climate oscillations was connected with periodical deterioration of deep-water oxygen conditions. The hypoxic events leaded to the mass mortality of benthic organisms and fish resources decrease. Hypoxia resulted in phosphate release from bottom sediments stimulating cyanobacteria blooms and eutrophication.

GP-P12

Global learning for local solutions: Reducing vulnerability of marine-dependent coastal communities

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The project 'Global learning for local solutions: Reducing vulnerability of marine-dependent coastal communities' (GULLS) falls within the Belmont Forum and G8 Research Councils Initiative on Multilateral Research Funding. Participants include teams from nine countries: Australia, Brazil, India, Madagascar, Mozambique, New Zealand, South Africa, the United Kingdom and the United States of America. The project focuses on five regional 'hotspots' of climate and social change, defined as fast-warming marine areas and areas experiencing social tensions as a result of change: south-east Australia, Brazil, India, South Africa, and the Mozambique Channel and adjacent countries of Mozambique and Madagascar. These areas require most urgent attention and serve as valuable case studies for wider applications. The project aims to assist coastal communities and other stakeholders dependent on marine resources to adapt to climate change and variability through an integrated and trans-disciplinary approach. Combining best available global knowledge with local knowledge and conditions, it is exploring adaptation options and approaches to strengthen resilience at local and community levels, with a focus on options for reconciling the needs for food security with long-term sustainability and conservation. The project will also contribute to capacity development and empowering fishing communities and other fisheries-dependent stakeholders.A standardized vulnerability assessment framework is being developed that will be used to integrate results from natural, social and economic studies in order to identify needs and options for strengthening management and existing policies. Structured comparisons between the hot-spots will assist global efforts for adaptation and strengthening resilience in marine and coastal social-ecological systems.

GP-P13

Ocean acidification and global warming impair behaviour and growth in an apex predator

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Apx predators typically exert substantial top-down forcing on trophically structured food webs, but there is lack of understanding how this function might be altered due to global change. We studied the effects of warming and acidification on the development, growth, and behaviour in a predatory fish species. Our results show that the projected increases in ocean temperature and CO_2 are likely to act synergistically on predators by not only increasing energetic demands, but also decreasing metabolic efficiency and reducing food intake. Alteration in growth and feeding of predators has important implications for the health and functioning of ecosystems.

GP-P14

How trophic interactions (*Littorina obtusata/Ascophyllum nodosum*) may be endangered by climate change

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The main goal of this work was to evaluate the synergistic effects of ocean warming and acidification on the success of the marine trophic model *Littorina obtusata* (gastropoda) and its dietary prey *Ascophyllum nodosum* (brown macroalga). Particularly, we investigated the effects of climate change on the oxidative stress (heat shock proteins and antioxidative enzymes) of both grazer and seaweed, the grazing capacity and the survivorship rates of the grazer. Little information on this topic is available in the literature, but the present study is one of the few works that can surpass this knowledge gap.

A short-term mesocosm experiment (20 days) was implemented with different temperature and pH conditions (treatment 1: temp. 18ºC, pH 8.0; treatment 2: temp. 18ºC, pH 7.6; treatment 3: temp. 22ºC, pH 8.0; treatment 4: temp. 22ºC, pH 7.6) according to the IPCC projections.

The results demonstrated a high mortality rate of *L. obtusata* at treatment 3 (76%), followed by treatments 1 (57%) and 4 (56%). Treatment 2, with low temperature and pH, seemed to gather the preferential conditions for *Littorina obtusata*, since mortality rate was the lowest of all treatments (19%). Both macroalgae and grazers were negatively affected in terms of oxidative stress. Also, a higher grazing activity was observed in treatment 2 (18ºC pH 7.6) and 4 (22ºC pH 7.6), surprisingly both with the lower pH values. It seems that warming had higher negative effect than acidification on this gastropod species and consequently on the top-down effects on macroalgae.

These results demonstrated that the *L. obtusata* survival may be endangered and consequently the success of the interaction between grazers and macroalgae may be threatened.

GP-P15

A safer catch? The effects of catch share management on fishing safety

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Fishing is the most dangerous job in the United States. When fisheries management creates the incentive to "race for fish", a fishing season can be reduced to only a few days and involve around-the-clock fishing in life-threatening weather conditions. Overloaded vessels, ignoring maintenance problems on vessels, and fishing in dangerous conditions may be commonplace. However, catch share management can reduce the incentive to race for fish, and one of the many results of catch share management has been a significant decrease in the speed and intensity of fishing and a lengthening of the fishing season. This is expected to increase safety in fisheries, as fishermen no longer need to work around the clock, they can return to port for repairs if something goes wrong with their vessel, and they do not need to fish in stormy or dangerous conditions. We evaluate the effect of the transition from limited entry to catch share management on risk-taking behavior in West Coast sablefish tier limit fishery. The probability of fishing in poor weather conditions (spatially averaged maximum daily wind proxies weather conditions), conditional on expected profits, describes a captain's propensity for risk taking. We find that captains are more risk averse when the race to fish incentives is eliminated, resulting in an 85 percent decrease in fishing on stormy days.

Cancelled

Quantitative analysis of planktonic thraustochytrids using flow cytometer

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Thraustochytrids are a group of heterotrophic, unicellular and fungal-like marine protest and featured with the presence of noncellulosic sulfurylated cell wall and ectoplasmic net elements. Recent findings of their abundance in coastal and oceanic waters suggest that they potential play significant ecological role in the ocean carbon cycling. Their enumeration has commonly carried out using acriflavine direct detection method under epifluorescence microscope. This method is labor intensive and easily plagued with human errors. To address the current obstacles in studying of this interesting group of marine microbes, this work will present our recently-developed flow cytometer based method for quantifying analysis of planktonic thraustochytrids in the coastal waters of Bohai Bay (China).

GP-P16

Paleoproductivity in the northeast Pacific for the last millennium

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Eastern Tropical North Pacific is characterized by high primary production, intense coastal upwelling and suboxic conditions in the water column with a lower degradation rate of organic matter (OM). These conditions help to conserve the exported OM. This has been used in primary productivity reconstruction to explain the variability in different time scales and have a better understanding about biogeochemical cycling. In this study we present new data of Biogenic Opal (OB), Organic Carbon (CO) and Chlorins in a high resolution record from western coast of Baja California Sur, Mexico. For the period to 600 to 700 yrs the OB showed a significant increment suggesting optimum condition in water column for diatoms blooms or more robust diatoms, in this period the primary productivity was dominated for the diatoms group. The trend of Chlorins and CO was synchronic in all record both showed an increment in primary productivity for the last to 200 yrs. of millennium suggesting permanent upwellings.

GP-P17

Are intertidal shrimps more vulnerable to global warming than subtidal ones?

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Intertidal habitats are among the most physically challenging environments on earth due to its marked fluctuations in air and water temperature. Previous studies suggest that species inhabiting these habitats may be at greater risk from global warming since they live closer to their upper thermal limit. The present work aimed to determine the effects of environmental warming on the ecophysiology of *Palaemon* shrimps inhabiting intertidal (*Palaemon elegans*) and subtidal (*Palaemon serratus*) zones. More specifically, we investigated the impact of a short-term acclimation process (30 days) at two different temperatures (12ºC and 20ºC, corresponding to winter and summer temperatures, respectively) on: i) upper thermal limits (CTMax), ii) heat shock protein 70 (HSP70) response, iii) routine metabolic rates, iv) lipid peroxidation (indicator of cellular damage), v) lactate content and vi) activity of several antioxidant enzymes. Our results show that, in general, *P. elegans* is more resistant to environmental warming than its subtidal congener. These findings suggest that intertidal species, despite living near their temperature maxima, still have room for maneuver to resist to global warming scenarios, contrary to what have been advocated.

GP-P18

A potential tool for detecting Harmful Algal Blooms through remote sensing data

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Harmful Algae Blooms (HABs) are algal/cyanobacterial proliferations that have harmful socio-economic or ecological effects, generally associated with natural toxin production and dissolved oxygen depletion. Their occurrence pose an emerging threat to Eastern Boundary Upwelling Ecosystems; nutrient-rich and highly productive areas that sustain large portion of fisheries global production. Traditionally, the study of HABs relies on *in situ* surveys, but facing the complexity and increase in frequency, magnitude and geographic extent of them, new multidisciplinary and methodological approaches are necessary. By combining satellite-derived data and in situ measured physicochemical parameters, we assessed the possibility of detecting HAB occurrence. We explored the scope of a colorimetric index (Red Tide Index), taking as a study case an event reported in the Humboldt Current System south of Chile between April 2003 and August 2004. According to the *in situ* data, the occurrence areas were characterized by a low subsurface percentage of oxygen saturation and high concentrations of nitrates, phosphates and total inorganic carbon near the coast. The index was able to distinguish those areas affected by the HAB as observed with *in situ* data. Our results indicate that satellite data could potentially be used as a proxy for detecting HABs.

GP-Posters

GP-19

Estimating the effect of pressure on the TRIS buffer system for in-situ pH measurements

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Recently, autonomous sensors have been developed to profile the in-situ chemistry of a water column. By providing extensive, long-term data, these sensors are increasing our understanding of the state of oceanic pH and overall trends in acidification. Measurements obtained from these sensors should account for the effects of in-situ physical parameters, such as temperature, salinity, and pressure on the chemical equilibriums of the system. TRIS-HCl buffers are frequently used to calibrate pH measuring systems, however the effect of pressure on its equilibrium constant (K) is yet uncharacterized.

The effect of pressure on the equilibrium constant (K^P/K^0) of weak acids can be estimated from data of the partial molal volumes ($\overline{V}^0$) and compressibilities ($\overline{\kappa}^0$) taken at atmospheric pressure. We have measured the density and sound speed of TRIS and TRIS-HCl in water, 0.725m NaCl, and seawater to determine values for $\overline{V}^0$ and $\overline{\kappa}^0$ as a function of temperature. The results are used to estimate the effect of pressure on the dissociation of TRIS-HCl up to 1000 bars. We report that the equilibrium for the TRIS buffer can be reduced by as much as 16% at pressures of 1000 bars which can affect the accuracy of autonomous pH sensors. The resulting equations will be useful for improving the calibration of autonomous pH sensors as they gain popularity in global ocean chemistry studies.

GP-20

Predictions of retreat of coastline up to 2025, 2050, 2075, 2100, depletion of sand and effect of sea level rise along gulf of Benin in Eastern Atlantic Ocean

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In the long characterized segments of beaches of erosion, of transport and sedimentation, the process of coastal erosion is rather well controlled by the advanced researchers working on the combination of morphodynamic, coastal hydraulicity and sedimentary fluxes. It is explained by an overdrawn sedimentary budget on long distance, 40 km on the coast of Togo and its impact is 10 m on average into 2014, speed of retreat increasing by effects combined of significant volume of break waters and a lack of sedimentary compensation. The increase in the temperature 2°C according to model RCP2.6, effective in 2030/2035, reinforces knowledge on the dilatation of marine water, on the deglaciation and the gravitation of polar water towards the tropical marine zones. This couple of reasons leads to sea level rise in the gulf of Benin where the only maregraphic station of Takoradi brings data to locate the marine levels up to 2030, 2050, 2075, 2100. New models make it possible to better center research on sea level rise taking account of the temperature, without taking into account the wind, factor of the agitation of the sea. The economy is the response of these combined effects, using the method of material accounting to judge the degrees of affectation, to characterize the limited adaptations and mobilities of people and to distinguish the withdrawals and recombinings of new areas.

W2 and W6 Posters
Joint Brazilian Ocean Acidification Research and Surface Ocean-Lower Atmosphere Study (SOLAS) Workshop: Biogeochemical-physical interactions and feedbacks between the ocean and atmosphere

W2/W6-P1

Response of Brazilian phytoplankton to temperature and ocean acidification

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According to the Intergovernmental Panel on Climate Change (2013), currently atmospheric CO_2 levels are estimated at 387 ppm with an annual increasing rate of 0.5%. As a consequence of the increasing atmospheric carbon dioxide concentrations, the surface ocean is facing parallel changes in the average temperature and carbonate chemistry speciation. The projected changes in the seawater carbonate chemistry are commonly referred to as ocean acidification which has deleterious consequences for calcifying marine organisms.

For this study, we chose Brazilian phytoplankton species from a culture collection and freshly isolated ones (*e.g. Emiliania huxleyi*, *Pseudo-nitzschia turgidula*). The study aims to better understand the physiological response and boundaries of the organisms to temperature and changing carbonate chemistry. This will be done by individually applying a broad gradient of temperature and carbonate chemistry and monitoring the growth response of the selected phytoplankton species. Experiments will be conducted under laboratory conditions controlling and monitoring temperature and the seawater carbonate chemistry. The species response curves will provide essential data on phytoplankton physiology that ultimately can feed ecosystem models predicting possible changes in phytoplankton community structures induced by anthropogenic climate change.

W2/W6-P2

Carbon flows through a coastal benthic community under ocean acidification conditions

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The progress of anthropogenic CO_2 emissions and the uptake by the oceans has caused rapid changes in the ocean chemistry, reducing the seawater pH and leading to the Ocean Acidification (OA). Although the ocean chemistry and their changes caused by OA are well understood, the effects of ocean acidification in the marine ecological process and trophic interactions involving benthic organisms are largely unknown. To address whether high CO_2 levels affect the transfer of fresh plankton-derived organic matter to the benthic food web, a short-term laboratory pulse-chase experiment was carried out. The experiment simulated a high spring bloom reaching the sea floor with ^{13}C-labelled nanoflagellates (*Tetraselmis* sp.). Analysis of carbon ($\delta^{13}C$) at natural abundance and as a tracer was used to examine the food web interactions and carbon flows. Intact sediment cores were collected by scuba diving in a coastal system of São Paulo State (Ubatuba, Brazil) and maintained in laboratory for 11 days in constant temperature and oxygenation, and in natural seawater pH (8.1, Control) and extreme low pH (7.3, OA) conditions. Consumption of the microalgae auditioned were observed and preliminary results from key macrofauna species reveled that pulses of food supply due of fresh organic matter are probably essential not only for macrofauna maintenance and survival but also for ecosystem function and carbon cycling in food-poor environments. The effects regarding other benthic compartiments (*i.e.* meiofauna and bacteria) will also be evaluated. Our study will contribute to the knowledge gap regarding an important carbon processing in a changing ocean.

W2/W6-P3

An estimate of anthropogenic CO_2 distribution in Southwestern Atlantic

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CO_2 emission is known as a problem since 1896, when S. Arrhenius published the first study about the effects it can bring to the Earth. Since then, many studies were made trying to understand and quantify these effects on marine ecosystems, due to the sink ability of the oceans. Nowadays carbon dioxide absorption by the global ocean is considered to be around 48% of total human emissions. This work aims to better understand the penetration of anthropogenic carbon (C_{ant}) in the Southwestern Atlantic. We used CARINA and GLODAP databases to quantify the C_{ant} in a wide-ranging section (25-50°S, 35-50°W) through two different approaches (and). Each method is based upon particular principles, although using the same initial parameters (T, S, DO, TCO_2, and TA). Taking into account that this section is affected by many large-scale oceanographic processes, the distribution and spatial variations of biogeochemical properties were associated with several water masses (*e.g.* South Atlantic Central Water, Antarctic Intermediate Water, North Atlantic Deep Water, Antarctic Bottom Water). Distinct values of C_{ant} were estimated by each method, although both showed a similar spatial distribution. The results indicated that the whole water column is affected by C_{ant}, in agreement with previous studies. These results reinforce that oceans play an important role in the absorption of CO_2 released to the atmosphere by human activities and inserted into the deep oceans layers.

W3 Posters, Group 1
Effects of climate change on the biologically-driven ocean carbon pumps

W3-G1-P1

Seasonal and inter-annual changes of microbial activities in the Mediterranean Sea

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The aim of our study is to identify the microbial key components which could explain the biogeochemical variability of the Mediterranean. During ten cruises carried out from 1998 to 2012 in the Ionian Sea, different biochemical and microbial parameters involved in the biogeochemical cycles were measured and the changes in microbial transformation of organic matter checked. Inter-annual differences were significant in the euphotic layer for temperature comparing two winter periods 1998-99, when mean temperature increased from 15.168 to 15.794 °C. Conversely, temperature changes were not significant comparing two spring or summer and autumn periods. In the euphotic zone, inter-annual differences occurred in summer 2012 and 2001 for prokaryotic abundance which varied between 1.25×10^6 and 6.2×10^4 cell/ml, respectively.

Seasonal changes resulted in most of the microbial activities in the euphotic layer. The leucine-aminopeptidase activities (indicating protein hydrolysis) showed inter-annual and seasonal variations ranging from 0.39 to 0.11 µgC/l/h (winter 1999-autumn 2000, respectively) and beta-glucosidase, as indicator of polisaccharides hydrolysis, varied from 0.35 to 0.01 µgC/l/h, (winter 1999-summer 2001, respectively). Alkaline phosphatase varied seasonally from 3.10 µgP/l/h (autumn 2000) to 0.05 µgP/l/h (summer 2012). Also Heterotrophic Prokaryotic Production showed the maximum activity in autumn (both 2000 and 2004). High values of respiratory activity were detected in warm periods (0.25µg C/l/h) and winter 1998, while low values of respiration were observed in spring.

The variability of prokaryotic metabolic processes could be considered a good tool to understand the climate biogeochemical changes in act in the Mediterranean Sea.

W3-G1-P2

The microbial carbon pump: Potential significance in the globally changing ocean

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The microbial carbon pump (MCP), which was initially proposed in 2010, progressively transforms short-lived dissolved organic carbon (DOC) into long-lived compounds (lifetimes ≥100 years, *i.e.* semi-refractory and refractory DOC) by water-column microbial processes. The three vertical ocean carbon pumps described 30 years ago, *i.e.* the solubility, carbonate, and soft-tissue (or biological, BCP) carbon pumps maintain the gradient in Total CO_2 between surface and deep waters. Similarly, the MCP maintains the DOC gradient between shorter- and longer-lived DOC. Because the BCP and the MCP both sequester carbon (the BCP in deep waters, and the MCP at any depth as long-lived DOC), they both have biogeochemical and climate relevance. We reformulate the MCP concept in biogeochemical terms, and use the reformulated MCP concept to explore the potential contributions of that carbon pump to the present and future responses of biogeochemical carbon fluxes to the globally changing ocean.

W3-G1-P3

Typhoons impacts on sea-air exchanges of CO_2 and DO in the South China Sea

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This paper introduces two recent studies where typhoons enhanced sea-air exchanges of both CO_2 and dissolved oxygen (DO), based on both satellite information and in situ data in the South China Sea (SCS). (1) Ship measurements made two days after the passage of one typhoon (April 2011) showed two contrasted responses of the partial pressure of CO_2 at sea surface ($pCO_{2,sw}$). In low sea-surface salinity (SSS) water, $pCO_{2,sw}$ was low (349 ± 7 μatm), and the area was a carbon sink (-4.7 ± 1.8 mmol CO_2 m^{-2} d^{-1}), whereas in water with high SSS and Chl-*a* and low DO and SST, $pCO_{2,sw}$ was higher than for normal SCS water (376 ± 8 vs. 362 ± 4 μatm) and the area was a carbon source (1.2 ± 3.1 mmol CO_2 m^{-2} d^{-1}). (2) In-situ data were collected one week after another typhoon (Nanmadol, Aug 2011). An increase in DO concentration, accompanied by a decrease in water temperature and an increase in salinity and Chl-*a* concentration, was measured close to the typhoon track. Maximum DO concentration was found at a depth of around 5 m and maximum Chl-*a* concentration at depths between 50 m and 75 m. The layer of high DO concentration extended from the surface to a depth of 35 m; also a large sea level anomaly (21.6 cm) and high value of Ekman pumping velocity (4.0×10-4 m s^{-1}) were observed, indicating an upwelling phenomenon. Those studies indicate that typhoons can turned local water from a carbon sink to a source temporarily, and can also increase DO in the affected waters.

W3-G1-P4

A new look at ocean carbon remineralization for estimating deep-water sequestration

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Carbon sequestration in deep waters and sediments of oceans depends to a great extent on the uptake of CO_2 by marine plankton at the surface, and subsequent sinking of particulate organic carbon (POC) through the water column. Most of the sinking POC is remineralized during its downward transit and modest changes in remineralization have substantial feedbacks on atmospheric CO_2 concentrations, but little is known about its global variability. Here we assess this variability based on modern underwater particle imaging combined with historical POC flux data. We obtain the first regionalized estimates of remineralization in 56 biogeochemical provinces, and find that these estimates range between-50 and+100% of the commonly used globally uniform remineralization value. The corresponding regional *e*folding depths of POC range between~130 and 800 m. We apply the regionalized values to satellite-derived estimates of upper ocean POC export to calculate regionalized and ocean-wide deep carbon flux. The resulting value of global organic carbon sequestration is 0.33 Pg C year[1], 30% higher than the value resulting from the commonly-used approach based on uniform remineralization. These results stress that variable remineralization values should be used to estimate or model ocean carbon sequestration and feedbacks on the atmosphere.

W3-G1-P5

Carbon pump dynamics and budget for the Northwestern Atlantic shelf

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Continental margins play a substantial role in the global carbon cycle due to their elevated annual rates of carbon fixation, remineralization and burial as compared to the adjacent interior ocean. Compilation of U.S. east coast margin data sets of particulate organic carbon (POC) fluxes, resuspension, offshore advection, and sediment accumulation rates reveals that the Gulf of Maine contributes significantly to the total east coast domain budget of POC export and burial. Our regional synthesis indicates that although a majority of the surface-produced, sinking POC is rapidly remineralized in the relatively shallow Gulf of Maine water column, sedimentary carbon accumulation is 2-3 times larger than that reported for the Mid- and South Atlantic Bight regions. Additionally, a large, previously over-looked carbon inventory exists in benthic nepheloid layers (BNLs) on the shelf. The persistent BNLs, exhibiting elevated biological activity, represent geochemical transformation layers which modulate the balance between carbon remineralization, benthic delivery and offshore transport. Estimated potential lateral movement of the shelf BNLs to the adjacent deep North Atlantic slope represents an offshore input of approximately 11 Tg C per year. Multi-year, time-series particle fluxes collected in the Gulf of Maine reveal decadal decreases in carbon delivery coincident with surface warming and decreasing salinity. Near-bottom pCO_2, pH, DIC, total alkalinity and particle beam attenuation data sets provide evidence of seasonal carbon remineralization driven by coupled biological-carbonate pump oxidation and dissolution reactions occurring in shelf benthic nepheloid layers.

W3-G1-P6

Manna from heaven… Role of aeolian nutrient inputs on carbon pumps in the contemporary and future ocean

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In the World Ocean, primary production is limited by the availability of the nutrients, and this in turn has important effects on ecosystem processes, ocean biogeochemistry and the export and sequestration of organic and inorganic carbon. Nutrients are supplied to the surface ocean mainly by atmospheric deposition or mixing from deeper waters. Atmospheric wet and dry depositions of nutrients are important controls on ocean biogeochemistry. Deposition of N could account for up to about a third of the ocean's "new" nitrogen supply. In open-ocean regions the input of iron is dominated by the atmospheric sources and modeling studies suggest that~20% of the global net primary production is supported by the atmospheric deposition of N and Fe. In addition to inorganic nutrients, rain is a significant source of dissolved organic carbon (DOC) to the ocean, it is equivalent to the global riverine input, and this DOC would potentially enhance heterotrophic bacterial production and uncouple it from primary production. Although it is recognized that atmosphere-derived nutrients can influence oceanic production, the effect on the biological and microbial carbon pumps has not been considered. These pumps sequester carbon in the ocean by maintaining a CO_2 gradient between the surface and deep waters or between shortand long-lived DOC. It is proposed that these carbon pumps will respond differentially to the atmospheric inputs of macro- micro and organic nutrients. Here we systematically examine the potential influence of the atmospheric inputs of inorganic macro- and micronutrients and DOC on the pelagic food webs and the effects on the biological and microbial carbon pumps in the contemporary and future ocean.

It is predicted that these carbon pumps will respond differentially to the atmospheric inputs of macro- micro and organic nutrients, because the carbon pumps (*i.e.* influence on carbon between the surface and deep waters, or would maintain a gradient between short and long-lived dissolved organic carbon and have an important effect on the air-sea CO_2 fluxes on century timescales.

These three pumps maintain the vertical gradient in total dissolved inorganic carbon between the surface and deep waters. The more recently proposed microbial carbon pump (MCP) would maintain a gradient between short and long-lived dissolved organic carbon (DOC; average lifetimes of <100 and >100 years, respectively). Long-lived DOC is an additional proposed reservoir of sequestered carbon in the ocean.

These pumps sequester carbon in the ocean by maintaining a gradient in total dissolved inorganic carbon between the surface and deep waters or between short and long-lived DOC carbon pumps maintain the vertical gradient in total dissolved inorganic carbon between the surface and deep waters and have an important effect on the air-sea CO_2 fluxes on century timescales.

Here we systematically examine the potential influence of the atmospheric inputs of inorganic macro- and micronutrients and dissolved organic carbon on the pelagic food web and the effects on the biological and microbial carbon pumps in the contemporary and future ocean.

W3-G1-P7

Variability of carbon dioxide production rates in the water masses of Southern Adriatic Pit in the period 1993-2004

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During the last century, the global increase in fossil fuels consumption together with the reduced capacity to remove CO_2 due to deforestation, have caused a dramatic input of carbon dioxide into the atmosphere. The resulting enhancement of the natural Greenhouse Effect is partially balanced by sequestration of CO_2 in the deep oceanic waters. In fact, topical studies have supported the significant role of the oceanic biological pump with respect to atmospheric CO_2 build-up.

In the marine ecosystem the biological pump controls the export of biogenic carbon from the surface layers down to the deep. In brief, this mechanism transforms in the euphotic zone, through photosynthesis processes, carbon dioxide into organic matter; the latter sinks to the waters below and at the same time are consumed by respiration with the production of metabolic CO_2. However, during the formation of dense waters, a significant quantity of organic products is conveyed from the surface within the water mass and remineralized inside it, thereby altering the normal flow of the biological pump.

In this study the evolution of carbon dioxide production rates (ETS activity) in a deep convection site of Eastern Mediterranean Sea (the Southern Adriatic Pit) in the period from 1993 to 2014 is reported in relation to climatic change.

W3-G1-P8

Variability of biological pump in the deep northern South China Sea

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In this presentation we will discuss the seasonal and inter-annually variation of the biological pump based on multi-year observation of biological pump at 1200 m by time series sediment trap in the northern and central South China Sea (SCS). The monthly averaged biogenic flux ($CaCO_3$, Opal and POC) exhibits strong seasonality with prominent peak in winter during northeastern monsoon period. Diatom productivity was also apparently higher in winter than in summer in the northern South China Sea, attributed to a positive response of diatom growth to increased nutrient supply from the subsurface as a result of enhanced vertical mixing and monsoon induced upwelling off NW Luzon in winter. On the contrary, strong stratification and the southwest monsoon induced basin-scale anticyclonic circulation resulted in low productivity of diatoms in summer. In addition to seasonally changing oceanographic environment, short-term environmental changes, such as meso-scale eddy activity and heavy aerosol deposition from the Asian dust storms, were also able to rapidly and strongly influence the biological pump in deep SCS. The inter-annually variation of the biological pump in SCS was controlled by ENSO induced oceanographic variability in northern SCS, the most distinct consequences was dramatically decreasing of diatom and biogenic fluxes during ENSO dominant period.

W3-G1-P9

Emerging needs for standard protocols for core measurements of the marine carbon sinks

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The ocean is the largest active carbon pool on the planet, and it plays a critical role in global carbon cycling and climate change as a buffer of atmospheric CO_2. The contemporary ocean has taken up 48% of the anthropogenic CO_2 since the beginning of the Industrial Revolution. The marine carbon sinks, however, was not included in the Kyoto Protocol two about decades ago, partly due to lack of measurable indices. Recently, the UN "Blue Carbon" report and the IPCC 2013 report both emphasized the role of the ocean in the carbon cycle and climate change. Hence the emerging need for marine carbon sink protocols. Here we emphasize the importance of developing a framework for core measurements of carbon sinks in variety of marine ecosystems (estuaries, wetlands, saltmarshes, continental shelves, open seas and oceanic gyres) with different dominant biological components (phytoplankton, bacteria, viruses, zooplankton, seagrasses, mangroves, fishes and farming species). This framework would allow researchers to work toward the development of standard protocols for comparable parameters in biogeochemical and ecological processes. Special attentions should be paid to new parameters such as those involved in the microbial carbon pump (*e.g.*, bacterial growth efficiency, refractory dissolved organic carbon bioassay, gene-chips-assay *etc*.). The protocols for the marine carbon sinks are not only necessary for scientific research and data sharing, but also underline coastal management of river discharge control, land-ocean integrated ecological compensation, as well as future carbon trade.

W3-G1-P10

Microbial gardening in the ocean's twilight zone: Detritivorous metazoans benefit from fragmenting, rather than ingesting, sinking detritus

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Organic particles that sink into the deep ocean help keep the atmospheric CO_2 concentration significantly lower than it would otherwise be. Organisms inhabiting the ocean's twilight zone (~50-1000m beneath the surface) remineralize sinking organic carbon, thereby influencing the efficiency of oceanic carbon storage. Zooplankton in the twilight zone appears to fragment, rather than ingest, the majority of encountered organic particles, thereby stimulating the proliferation of bacteria and the associated communities of heterotrophic flagellates and ciliates. We develop the idea that this apparently counterintuitive behaviour is an example of 'microbial gardening', a strategy that exploits the catabolic and anabolic capabilities of microorganisms to facilitate the 'gardeners'access to a suite of otherwise unavailable micronutrients that are essential for metazoan life. We explore this concept using a simple steady state model and highlight the benefits and limits of this trophic strategy.

W3 Posters, Group 2

W3-G2-P11

On the impact of soot deposition on carbon pumps

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Black Carbon (BC) is an aerosol emitted as soot during biomass burning and fossil fuels combustion. A large fraction of atmospheric BC deposits on the surface of the ocean and enters marine ecosystems at a global rate of about 12 Tg C per year. Owing to their high surface-active properties, BC modifies the functioning and the structure of the microbial ecosystem by adsorbing dissolved compounds and microorganisms. We show evidence for various BC-induced processes, such as: the adsorption of dissolved organic matter followed by an enhanced formation of marine aggregates, and the adsorption of viruses and bacteria followed by an increase in the activity of particle-attached bacteria. As for its carbon cousin the CO_2, BC has intertwined relationships with climate change in the sense that climate change influences BC emission and deposition patterns and rates, and atmospheric BC is a major player (right next to CO_2) in climate change. However, the impact of BC on climate change could be even wider than solely inferred from its effects in the atmosphere due to its impact on both the Biological and the Microbial Carbon pumps.

W3-G2-P12

Role of viral lysis of plankton for the cycling of organic matter

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Viral lysis is a major cause of mortality for phytoplankton and prokaryotic plankton thus, influencing the production and oxidation of organic matter. In addition, lysis products are released as rather labile dissolved organic matter (DOM) and small cell debris. This viral shunt is another pathway of DOM remineralization. In this process, the ratio of labile to recalcitrant DOM is likely changed thus, influencing the microbial carbon pump. Also, there is evidence that viral lysis affects the biological pump, however, is still not clear whether (or under which conditions) the biological pump is primed (aggregation and export) or shirt-circuited (lysis products are respired in the surface layer). The effect of climate change on viruses is poorly studied, however, it is likely that increasing temperature and pCO_2 levels will influence host activity and infection patterns.

W3-G2-P13

Carbon dioxide production rates in the Ross Sea (Antarctica)

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Microbial respiratory activity in several sites of the Ross Sea was studied in the framework of the Italian National Research Programme in Antarctica (PNRA), with the aim of evaluating the biological pump efficiency and the carbon flux transported by microbes throughout the water column. Recent studies have demonstrated that dissolved organic carbon (DOC) is an important component of the biological pump that assumed in the deep waters a key role as main organic fuel of microbial respiration. Such evidence seems overturned in the Southern Ocean where DOC pool accounted for < 10 % of the remineralization in deep waters. Moreover the euphotic zone of the Ross Sea yielded only a small portion of primary production as DOC (11 %), so that DOC removal by deep convection could be not an important export term due to the small quantity of DOC that accumulates there.

The purpose of this study was to investigate the supply and utilization of organic carbon in the aphotic zone of Ross Sea by evaluation of microplankton respiratory activity and to compare the vertical carbon balance with different estimates of export production from the same area and other oceanic regions.

W3-G2-P14

Variability of microbial respiratory activity in relation to particulate organic matter over short time scales in a glacial Arctic fjord (Kongsfjorden, Svalbard)

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Sinking biogenic particles drive respiration in the ocean interior, help to maintain the ocean's strong vertical gradient of inorganic carbon and related studies are important to determine the flow of organic matter along the water column. Sediment trap studies have shown that a low percentage of the surface primary production reaches the bottom. However, organic matter collected by sediment traps does not take into account the entire pool of oxidable organic matter, which includes the dissolved organic matter present in the seawater. The study of microbial respiration rates instead fills this gap, since respiration includes oxidation of both dissolved and particulate organic mater, providing an integrated estimate of the carbon utilization in the sea. In this context, a study on an Arctic fjord (Kongsfyorden, Svalbard) was done in late summer 2013, with the purpose of knowing the variability of microbial remineralization rates in relation to particulate organic matter over short time scales in a coastal station (water depth~105 m), where a mooring (Mooring Dirigibile Italia, MDI: 78° 54 .859'N; 12° 15. 411' E) is positioned.

A high variability of carbon dioxide production rates was recorded during the sampling days and this result was related to several factors. Useful information may be deducted for modelling studies of carbon flux in similar areas.

Cancelled

Ecological significance of mycoplankton in carbon cycling of the world's oceans

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Planktonic microbial communities are key players in microbial food-web and nutrient cycling of the world's oceans. Large populations of mycoplankton (planktonic true fungi and thraustochytrids (fungal-like protest)) have long been known to exist in coastal and oceanic waters, yet their diversity and ecological functions remain largely unknown. Our recent studies on the diversity of mycoplanton in several ocean environments (*e.g.*, Pacific Warm Pool, China's and Atlantic coastal waters) indicated that enormous novel diversity of mycoplankton remain to be discovered in the ocean and their biomass can surpass that of bacterioplankton. These findings suggest that mycoplankton can play significant roles in carbon and other nutrient cycling of the world's oceans. Along with findings by several other research groups, a working model of mycoplankton in ocean nutrient cycling will be discussed. Future work on these under-studied marine microbial groups may bring new information to our current understanding of the landscape of microbial food web.

W3-G2-P15

Viral control on bacterioplankton and its ecological and biogeochemical implicates in the deep western Pacific Ocean

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As the most abundant biological entities in the ocean, viruses play an important role in marine ecosystem and biogeochemical cycles. Viral lysis are now considered as major contributing factor of bacterial mortality, controlling the abundance, production, diversity and community structure of their hosts in marine environment. Yet the ecological characteristics of virioplankton and viral impacts on host mortality and biogeochemical cycling in the deep sea are largely unknown. In present study, viral abundance and lytic infection was investigated throughout the water column in the western Pacific Ocean. Both the prokaryotic and viral abundance and production showed a significantly decreasing trend from epipelagic to meso- and bathypelagic waters. Relatively high percentages of prokaryotic cells lysed by virus in 1000 m and 2000 m were observed, suggesting a significant contribution of viruses to prokaryotic mortality in deep ocean. In addition, bacterioplankton in deep-sea water in the Western Pacific Ocean were manipulated with in situ virioplankton by experimental setup of filtration and dilution to develop +virus and -virus treatments. Flow cytometry results showed that deep-sea viruses had significant repressing effects on bacterial abundance. The changes of bacterial community compositions suggested that bacterial species compositions were regulated by viruses. Our findings demonstrated a highly dynamic and active viral population in the deep western Pacific Ocean and suggested that virioplankton play an important role in the microbial loop and biogeochemical cycling in deep oceans.

W3-G2-P16

Roles of archaea in organic matter degradation in marine sediments

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Microbial carbon pump (MCP) is now recognized as important carbon cycling process in the ocean waters, by which labile organic carbon is transferred to recalcitrant organic carbon. Climate change has (and is having) strong influences on the biological systems (including MCP) and their mediated carbon cycling in the surface oceans. Recent investigations also suggested that the influences of climate changes on the biological system could be observed in the deep waters more than 4000m in depth. However, very limited data is available for the deep ocean carbon cycling, even nearly nothing is known for the possible impacts of climate changes on the benthic ecosystems in the sediments, and/or their feedbacks.

Overall, less than 1% of organic matter produced in the surface oceans could be finally transferred and buried in the marine sediments. Meanwhile, organic matter could also be produced *in-situ* by chemotrophic organisms in the dark, the scale is currently unknown. Biological systems in the marine sediments are largely influenced by the quantity and quality of the buried organic matters. Unfortunately, our current knowledge on the microbial mediated organic matter in marine sediments remains to be poor, in particular the roles of archaea in the carbon cycling is nearly unknown. Marine sediments contain large number of archaea, most of which are still uncultivable in the laboratory, remain their phylogenetic position, physiology, and ecological roles unresolved. The most abundant and widely distributed sedimentary archaea are lineages such as Marine benthic group B (MBG-B), MBG-D, Miscellaneous Crenarchaeota Group (MCG, recently assigned as a novel phylum "Candidatus Bathyarchaeota"). Here, I'll report our recent investigations on the roles of uncultivated archaea (MBGD and Bathyarchaeaota as representatives) on carbon cycling using a combination of geochemical, genomics, and cultivation approaches. We propose that many of the uncultivated archaea in marine sediments take part in the transformation of recalcitrant organic matters, play a key role in the carbon cycling in marine sediments. Illustrating the roles of microbes in the sedimentary carbon cycling would be the first step towards understanding the impacts of climate change on the ecosystem therein.

W3-G2-P17

Variability in abundance of the Bacterial and Archaeal 16S rRNA and *amoA* genes in water columns of northern South China Sea

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Recent advances in marine microbial ecology have shown that ammonia-oxidizing Archaea (AOA) is more abundant than ammonia-oxidizing bacteria (AOB). This study aimed to examine the spatial distribution and abundance of planktonic archaeal and bacterial 16S rRNA- and *amoA* genes in the northern South China Sea. Water samples were collected at six stations (maximum depth ranging from 1800 m to 3200 m with four stations (B2, B3, B6, B7) located along a transect from the northeastern continental slope to the Bashi Strait and the other two (D3, D5) located southwest of this transect. Quantitative PCR targeting the 16S rRNA- and *amoA* genes was used to estimate the abundances of total Archaea, total Bacteria, and AOA and AOB, respectively. The abundance of bacterial 16S rRNA gene was 2-36fold higher than that of the archaeal 16S rRNA gene at the B series stations, but fivefold lower to sixfold higher at the two D stations, with both genes showing peak values slightly below sea surface (5-75 m depths) at all stations. The archaeal *amoA* gene was 1-4 orders of magnitude lower than the archaeal 16S rRNA gene at all stations. Bacterial *amoA* gene was below detection limit at all stations, which indicates that AOA are the dominant group of microorganisms in nitrification of the South China Sea.

W3-G2-P18

Marine Ecosystem Experimental Chamber System (MECS) – A powerful tool for scenario studies on climate and environmental changes

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The responses and feedbacks of the ocean to anthropogenic and climate changes are of critical importance for the sustainable development of human societies. The principal means to study such complex issues are field observations and laboratory experiments: the former is the closest to the natural environment, and the latter provides parameters that are not easily acquired by the former. In between the two approaches is the simulated *in-situ* seawater enclosure system termed "mesocosm". Here we propose a new type of simulated experimental facility called Marine Ecosystem Experimental Chamber System (MECS), which is an array of land-based water columns with sizes of 30 to 50 m high and 5 to 8 m in diameter. The MECs would consist of multiple operational modules that include seawater incubation chambers, temperature control, lighting, ventilation, filling, stirring, filtration, sampling, on-line monitoring, data processing, communication, *etc*. The MECs would allow a wide range of experimental manipulations of environmental variables for complex studies such as the biological, carbonate and microbial carbon pumps. The MECs could even be used for scenario studies simulating geological events such as global warming or cooling, ocean acidification, sulfidation, hypoxia, *etc*. The MECs would also be appropriate for studying sustainable development practices, such as carbon sink engineering. In addition, the MECs could be used for public education.

W3-G2-P19

Phytoplankton biovolume conversion carbon biomass calculation and its implication for biological pump

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Phytoplankton biovolume can be transferred to Phytoplankton Particle Organic Carbon (PPOC), it can be future used for tracking the carbon mass transport in the carbonate pump, the biological carbon pump, and the microbial carbon pump. Phytoplankton standing crop, growth, grazing mortality, sinking loss, trophic transfer efficiency, *etc*., all these parameters are related to PPOC, and play the important roles in biological carbon pump. I will give some examples on how to calculate the biovolume conversion POC and PIC, and its implication for biological pump studies in China Seas.

W3 Posters, Group 3

W3-G3-P20

Variability in efficiency of particulate organic carbon export: A model study

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The flux of organic carbon from the surface ocean to mesopelagic depths is a key component of the global carbon cycle and is ultimately derived from primary production (PP) by phytoplankton. Only a small fraction of organic carbon produced by PP is exported from the upper ocean, referred to as the export efficiency (herein e-ratio). Limited observations of the e-ratio are available and there is thus considerable interest in using remotely-sensed parameters such as sea surface temperature to extrapolate local estimates to global annual export flux. Currently, there are large discrepancies between export estimates derived in this way; one possible explanation is spatial or temporal sampling bias in the observations. Here we examine global patterns in the spatial and seasonal variability in e-ratio and the subsequent effect on export estimates using a high resolution global biogeochemical model. NEMO-MEDUSA represents export as separate slow and fast sinking detrital material whose remineralisation is respectively temperature dependent and a function of ballasting minerals. We find that both temperature and the fraction of export carried by slow sinking particles are factors in determining e-ratio, suggesting that current empirical algorithms for e-ratio that only consider temperature are overly simple. We quantify the temporal lag between PP and export, which is greatest in regions of strong variability in PP where seasonal decoupling can result in large e-ratio variability. Extrapolating global export estimates from instantaneous measurements of e-ratio is strongly affected by seasonal variability, and can result in errors in estimated export of up to ±60%.

W3-G3-P21

Effects of rising atmospheric carbon dioxide concentrations on the biological carbon pump

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The vertical separation of organic matter formation from respiration leads to net sequestration of carbon within the ocean's interior, making the biological pump an integral part of the global carbon cycle. Understanding the response of the biological pump is a prerequisite to project the future development of atmospheric carbon dioxide concentrations. Carbon flux at approximately 1000 m, the sequestration flux, determines the removal of carbon from the atmosphere on times scales of > 100 years. This sequestration flux depends on (i) input rates of nutrients allochthonous to the ocean, (ii) the efficiency with which nutrients from below are transported into the euphotic zone and utilized by phytoplankton, (iii) the flux attenuation in the upper 1000 m of the ocean, and (iv) the degree of decoupling of carbon fixation and remineralization from the *Redfield* stoichiometry. Nutrient utilization, flux attenuation, and the C:N ratios of organic matter production or respiration may all shift as organisms and ecosystems respond to changing environmental conditions.

W3-G3-P22

Sensitivity and regional change of future biological carbon pump to POC flux parameterization

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The ocean biological carbon pump is projected to decrease under the business-as-usual future scenario, leading to a positive climate feedback. The model projection is potentially sensitive to the parameterization of the vertical particulate organic carbon (POC) flux from surface to the ocean interior. In addition, changes in biogeochemical interaction with the evolving sea-ice and ocean circulation also lead to regionally heterogeneous responses. Using a relatively simple POC flux parameterization in a fully coupled Earth system model, our projection shows a net global reduction in export production out of the euphotic layer by roughly-10% by the end of the 21st century relative to the present day. Stronger stratification in the tropical and subtropical regions largely responsible for the reduction of surface production, whereas loss of sea ice leads to an increase in polar regions export production. In the Southern Ocean, higher export production is also simulated along the circumpolar front, which could be associated with Southern Annual Mode (SAM) intensification. A second set of simulation was performed applying a more sophisticated POC flux scheme, which takes into account different particle sizes and sinking speeds. We will present the sensitivity of the above mentioned climate change-induced biological carbon pump in respond to the new parameterization. Changes in key biogeochemical tracer distribution and climate feedback will be evaluated and presented.

W3-G3-P23

The continental shelf pump in the Adriatic Sea (Mediterranean Sea): Modeling the interaction between physical processes and the biogeochemical carbon cycle

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The Adriatic Sea (eastern Mediterranean Sea) is both a highly productive shelf area and a dense water formation site. The combination of productivity and dense water formation enhances the vertical transport of carbon into the interior of the Mediterranean Sea contributing to the sequestration of anthropogenic CO_2.

In this study, we investigate the air-sea exchange and the continental shelf pump process (solubility plus biological ones) by coupling the MITgcm general circulation model with a biogeochemical model of intermediate complexity that includes a carbonate dynamics module. The results of the numerical simulations show that the northern shelf is currently a CO_2 sink and that the C-rich dense water is accumulated in the deep layers of the southern Adriatic Sea. However, CO_2 fluxes and transport show significant temporal and spatial variability due to the interaction of several factors that affect the efficiency of the continental shelf pump. We investigate the role of these governing factors by means of an uncertainty analysis. Beside others, the winter cooling of the northern continental shelf is the most important factor influencing the solubility pump of CO_2 and the vertical transport of organic carbon out of the shelf into the deeper layers of the southern Adriatic Sea. In case of warm winter conditions, the mitigation of the solubility pump and the reduced dense water formation results in a significant reduction of the transport of carbon to the sea interior.

W3-G3-P24

The impact of climate change on aggregation and particle flux in the marine environment

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Aggregation of marine particles through physical or biological processes is a key mechanism affecting export of particulate organic carbon from the surface to the deep ocean. These aggregation processes depend on, among other things, physical motions that result in particle collisions, planktonic community structure, and mixed-layer processes. Climate change is predicted to lead to changes that can affect all of these processes, but the question of how it will affect aggregation and particle size distributions remains largely unanswered. It is already known that changes in mixed-layer depth affect the intensity of aggregation, with greater mixed-layer depths resulting in more opportunities for aggregation to occur. In this work I will present modeling results from a new, 1-dimensional coupled aggregation food-web model examining the effects of predicted changes in mixed-layer processes and planktonic community composition on aggregation, particle size distributions, and fluxes in the surface and mesopelagic waters. The model uses a simple representation of a planktonic food web, with different types of particles (*e.g.* phytoplankton of different size, fecal pellets *etc*.) contributing to marine snow formation and particle flux. The results from the model will investigate how the relative magnitudes of different export pathways change under a changing climate, and the implications this has for export production.

W3-G3-P25

Balancing the carbon budget in the twilight zone

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The rate at which sinking organic carbon is attenuated due to remineralization by microbes and mesozooplankton is believed to be a key control over ocean/atmosphere CO_2 partitioning. Current estimates of this attenuation in the twilight zone (100-1000m) are, however, at odds with estimates of remineralization in this region by up to an order of magnitude. Here we present a balanced carbon budget for the North Atlantic twilight zone using a combination of field data and modelling on particle export, mesozooplankton abundance and prokaryotic heterotrophic production from the Porcupine Abyssal Plain time series site (49ºN, 16.5ºW) in July/August 2009. Our data suggest that microbes are responsible for 70-92% of the twilight zone remineralization despite most of the organic carbon being exported in form of large, fast-sinking particles that are accessible to larger zooplankton. This is possible because zooplankton break up larger particles into slow-sinking and suspended matter, thereby stimulating the dark-ocean microbial loop. Our results emphasize a synergy between microbes and zooplankton in the twilight zone that is central to the functioning of the ocean carbon sink.

W3-G3-P26

Drivers of future changes in export efficiency in marine ecosystem models

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Future changes in marine particle export production (EP) are expected to have profound effects on oceanic carbon uptake, yet previous model comparison studies have focused on the drivers of net primary production (NPP) to explain changes in EP and barely discussed the drivers of changes in particle formation and particle sinking and their respective drivers. Here, we compare future projections generated by four different marine ecosystem models under IPCC's high emission scenario RCP8.5 with respect to changes in EP over the 21st century. Models suggest decreases in EP between -1% and -12%, however the drivers for the changes are substantially different. In one model, the changes in EP are almost entirely caused by changes in NPP. In the second model, NPP stays almost constant and the changes in EP are driven by lower particle formation, which is caused by lower biomass and lower diatom relative abundance. In the third and fourth model, both changes in NPP, particle formation and particle sinking substantially affect the changes in EP. However, in the third model more particles are formed relative to NPP but less are exported because of warming-induced increases in remineralization. In the fourth model, less particles are formed because of decreases in diatom biomass, and additionally particles are stronger remineralized, caused by a net effect of less ballasting with silicate, higher ballasting with $CaCO_3$ and higher temperature-driven remineralization.

W3-G3-P27

Particle attenuation simulated using a microbial remineralization model

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Organic particles sinking from the sunlit surface are oases of food for heterotrophic bacteria living in the deep ocean. Particle-attached bacteria need to solubilize particles, so they produce exoenzymes which cleave bonds to make molecules small enough to be transported through bacterial cell walls. Releasing exoenzymes, which have an energetic cost, to the external environment is risky because there is no guarantee that products of exoenzyme activity, called hydrolysate, will diffuse to the bacterium that produced the exoenzymes. Strategies used by particle-attached bacteria to counteract diffusive losses of exoenzymes and hydrolysate are investigated in a water column model. We find that production of exoenzymes by particle-attached bacteria is only energetically worthwhile at high bacterial abundances. Additional model results are that particle-attached bacterial production is sensitive to diffusion of hydrolysate from the particle and is enhanced by as much as 15x when diffusion of exoenzymes and hydrolysate from particles is reduced by barriers of biofilms and particle-attached bacteria. Bacterial colonization rates and activities on particles impact remineralization length scales. By linking variability in remineralization depths to mechanisms governing bacterial colonization of particles and group coordination of exoenzyme production using a model, we quantitatively connect microscale bacteria-particle interactions to the carbon cycle.

W3-G3-P28

Modeling carbon cycle in the Pacific Ocean

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The ocean plays an important role in regulating global carbon cycle by taking up and releasing carbon dioxide (CO_2). In this work, we use a coupled three-dimensional numerical modeling study to investigate the dynamics of carbon cycle in the Pacific Ocean. To elucidate the influence of anthropogenic CO_2, two modeling studies were conducted. The first one is the control run forced with measured atmospheric CO_2 from 1958 to 2010. The other one is a case run forced with the constant atmospheric CO_2 from 1958 (fixed at 1958 values). Both of the runs are integrated from 1958 to 2010 with the same initial condition and wind, heat, and freshwater forcing. The results from the control run were compared with available in-situ measurements. Long-term trends of these variables were also analyzed, which show conspicuous spatial variation that could be related to the local physical and biogeochemical processes. We separate the total carbon system (control run) into the internal one (case run for including natural climate variability) and the forced one (for including anthropogenic atmospheric pCO_2). Thus, we are able to investigate the pathway and penetration depth of the anthropogenic CO_2 in the Pacific Ocean, as well as the individual contributions from the internal (natural) component and the anthropogenic component. This modeling study allows us to look into the detailed mechanisms in regulating carbon cycle with high spatial and temporal resolutions.

W3-G3-P29

Comparison of microbial carbon pump (MCP) in several open ocean stations using an ecosystem model

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Refractory dissolved organic carbon (R-DOC) is produced in many microbial-mediated processes in the ocean and thus is stored for a millennial time scale. This form of carbon sink, recently termed as microbial carbon pump (MCP), has been proposed to alleviate the effects of anthropogenic CO_2 release. To quantify the MCP and compare its strength under different environmental conditions, we set up a microbial ecosystem model emphasizing DOC production and consumption pathways and including key MCP processes: active R-DOC release by heterotrophic bacteria, and passive R-DOC production in forms of bacterial cell walls under viral lysis. The model was applied to 3 open ocean stations in the oligotrophic North Pacific Subtropical Gyre, the equatorial Pacific with influence of upwelling and the Arabian Sea with seasonal monsoon-driven eutrophication. Data assimilation method was used to optimize model parameters with available observations from each station. The tentative results show different patterns of MCP among the stations, with highest MCP to primary production ratio in the oligotrophic station. We also tested the change of MCP with gradually stronger stratification over a period of 100 years. Although the ratio of MCP to primary production always increased in this experiment, as the primary production often underwent substantial decrease with limited nutrient supply, the MCP may increase or decrease in different scenarios. Our study reveals the importance of MCP in predicting future carbon sink, and calls for more field and laboratory measurements of key MCP-related parameters.

W3-G3-P30

Cumulative effects of climate change and other anthropogenic pressures on ocean carbon pumps

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Human activity modifies the environment and hence influences ecosystems. The impacts of climate change have usually been assessed independent of other natural and anthropogenic pressures. However, it is now established that cumulative effects of anthropogenic disturbance are threatening the stability and sustainability of marine ecosystems. Ecosystem responses to multiple stressors are complex, and can result in changes that are non-linear, with the responses to drivers being additive or synergistic. Climate change is one of several important anthropogenic pressures that affect the activity of, and balance between the three ocean carbon pumps. Planktonic communities will respond differently to various types of anthropogenic impacts, including eutrophication. Effluents from oil and gas exploitation and marine transportation can be significant sources of N, P and DOM which are largely ignored in nutrient budgets, and regional or global change models. Inorganic and organic nutrients from produced water, the dominant waste stream from offshore oil extraction lead to differential stimulation of autotrophic and heterotrophic food webs and a change in the balance between autotrophic and heterotrophic production, shifts in microbial community size distribution and concomitant changes in sinking flux of particles. Using examples from several regional seas (*i.e.* the Grand Banks, the North Sea and the South China Seas) we explore the potential for cumulative effects of climate change and other anthropogenic pressures related to oil and gas exploitation on the carbon pumps.

W5 Posters
Moving towards climate-ready fishery systems: Regional comparisons of climate adaptation in marine fisheries

W5-P1

Evaluating adaption options for four key fisheries in South Eastern Australia

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Planned adaptation to climate impacts must, by necessity, interact with existing strategies concerned with fisheries monitoring, assessment, management and decision making, as well as industry stewardship. Optimal adaptation options are those which enable negative impacts to be mitigated and opportunities that arise to be seized, both in relation to specific climate-driven changes and in relation to the broader fisheries system. Four key fisheries (Southern Rock Lobster, Abalone, Snapper and Blue Grenadier) in south-eastern Australia were selected as case studies on the basis of the high risk posed to these fisheries by climate change. We developed a step-wise approach to evaluating adaption options for the selected fisheries which enabled stakeholders to conduct a "first pass" assessment of options, entailing characterisation and then scoring of options against a range of criteria. Candidate options could then be further evaluated using existing risk-and-simulation techniques, and against management objectives. After ascertaining actual and expected key climate impacts via a separate study, potential adaptation options for each fishery were firstly described then prioritised using a characterisation matrix which included: the specific climate challenges addressed, the implications of each option on the fishery system as a whole (*i.e.* the interaction of adaptation options with other management strategies), as well as temporal and spatial scales of implementation processes and benefits. Semi-quantitative evaluation of the final list of options was undertaken by stakeholders scoring the anticipated performance or outcome of an option against a pre-determined set of criteria and related indicators relating to perceived feasibility, risk and benefit.

W5-P2

Following the fish? Fishery responses to shifting fish distributions in the Northeast United States

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In the Northeast United States, the spatial and temporal distributions of many commercially-important fish stocks are shifting in conjunction with changing climate and population conditions. Spatial distribution shifts are apparent in the range occupied by stocks as well as in the latitude and depth at which stocks are centered. Temporal distributions of some key commercial species closely track temperature, and these species are experiencing shifts in phenology in response to climate trends and events. While these distribution changes have been relatively well documented, the ability of fishermen to adapt to these distribution changes and the ways in which they respond has been less well-studied.

In this presentation, we use a variety of fishery-dependent data sources to evaluate relationships between temperature, species distributions, and fishing patterns. Our results show that some fisheries do respond in tight alignment with changes in species distributions. In general, there appears to be a more tightly coupled pattern of fishery response to changes in species' temporal distributions than to their spatial distributions. We offer several explanations for the weaker relationship between shifting spatial distributions and fishing patterns, including the need for learning as fishermen search for new fishing locations, management constraints that inhibit spatial

responses by fishermen, and shortcomings in our observation systems. These results lead to recommendations for scientific, governance, management, and incentive systems that can support the capacity of fisheries to adapt to climate-related species distribution changes.

W5-P3

Slow management during rapid ecosystem change: How rapid warming drove the collapse of Gulf of Maine cod

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Conditions in the ocean and the atmosphere vary across a range of time-scales. Biological processes within an ecosystem integrate these scales and determine the rate and magnitude of variability in the ecosystem. Fisheries management also has inherent time scales. For most fisheries, the most important scale is the annual-to-multiannual cycle of assessment and quota setting. Assuming assessments are accurate, this scale should be able to detect and correct for slow changes in the ecosystem. However, if conditions change rapidly over a long period of time, the management cycle can struggle to keep pace. From 2004 through 2013, the Gulf of Maine warmed at a rate of 0.23° yr^{-1}, one of the strongest decadal trends any marine ecosystem has ever experienced. This trend led to widespread changes in the ecosystem and coincided with the collapse of the fisheries for northern shrimp and Gulf of Maine cod. Error in the projections from the Gulf of Maine cod assessment is strongly correlated with temperature. This error appears as enhanced mortality that is not accounted for in the assessment. Not including this extra mortality led to fishing mortality rates that were consistently above targets. Directly incorporating temperature into the projections would have led to improved abundance estimates and may have avoided the collapse that is currently underway. Fisheries management has traditionally relied on historical patterns. As we encounter conditions with no analogue in our recent history, failures in our backwards-looking process will become more common.

W5-P4

Climate change and adaptive fisher behavior in the Pacific cod longline fishery

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Pacific cod is an economically important groundfish that is targeted by trawl, pot, and longline gear in waters off Alaska. An important part of the Bering Sea Aleutian Islands (BSAI) fishery is the "freezer longliner" sector which in 2008 accounted for $220 million of Pacific cod value.

The timing and location of winter fishing has shifted dramatically since 2000. This shift is related to the extent of seasonal sea ice and the timing of its descent and retreat. The presence of winter ice cover restricts access to a portion of the fishing grounds and affects relative spatial catch per unit effort (CPUE) by causing a cold pool (water less than 2°C that persists into the summer) that Pacific cod avoid. The cold pool is larger in years characterized by a large and persistent sea ice extent. Finally, climate conditions and sea ice may have lagged effects on harvesters' revenue through its effect on recruitment, survival, total biomass, and distribution of size and age classes. The availability and location of different size classes of cod, as well as the demand for these products, affects harvester's decisions about where to fish, what products to produce, and their revenue.

Understanding the relationship between fishing and climate variables is essential in predicting the effects of warming on the fishery. Here we examine the relationship between the location of the fishery, changing abundance, and changing sea ice. We also investigate how a fishing cooperative has impacted fisher behavior production since 2010.

W5-P5/S10-P1

Decline in puerulus settlement in the western rock lobster fishery in Western Australia: A climate change effect?

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The western rock lobster fishery is one of the best fisheries in Australia to examine effects of climate changes because of its long time series of data to assess trends in the fishery. Its location in the lower west coast of Western Australia has been identified as one of the hotspots of long-term increases in water temperature in the Indian Ocean and is also affected by a long-term reduction in winter storms. These trends are projected to continue. The decline in puerulus (post-larval stage) settlement in the seven years (2006/07 to 2012/13) appears to be due to long-term environmental factors. Water temperature increases in winter have resulted in an earlier onset of spawning which may be creating a mismatch with other environmental factors affecting the larvae during its 9-11 month larval phase. There has been a pro-active management response before these puerulus year-classes entered the fishery (3-4 year lag between settlement and recruitment to the fishery) with a significant reduction in fishing effort (~70%) since 2008/09. The fishery has also moved to a catch quota system with maximum economic yield as its target which has provided increased resilience to the stock. The fishery provides an example of an appropriate management adaptation response to the decline in recruitment abundance. The fishery has demonstrated the ability of research, management and industry to react quickly to changing abundance and highlights the value of reliable pre-recruit abundance for early detection of changes in abundance and early management adaptation response before fishing took place on the poor year classes.

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